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THE FLUTING AND PITTING OF GRANITES IN THE TROPICS.

(PLATES I–VIII.)

BY J. C. BRANNER.

(*Read April 4, 1913.*)

Fluting is a peculiar minor form of topographic relief, but where it occurs over an area large enough to attract attention, it is a very striking feature.

All geologists are familiar with the fluting of limestones, which is a common phenomenon all the world over. Many fine examples of the fluting of limestones are given in Dr. H. Stille's "Geologische Charakterbilder," 10 Heft, published at Berlin in 1912, in which they are called "Karren."

But the fluting of granites or of other crystalline rocks is, so far as I have been able to learn, confined to tropical, and possibly subtropical countries. Two cases that occur on the coast of the state of Pernambuco in Brazil were mentioned by me in a paper on rock decomposition published in 1896.[1] Since that paper was published I have seen in Brazil some very striking examples, and have seen photographs of several others. Good examples are also cited by Max Bauer, who speaks of them as furrows (Rillen).[2]

[1] J. C. Branner, "Decomposition of Rocks in Brazil," *Bul. Geol. Soc. Amer.*, VII., 280, Rochester, 1896.

[2] *Neues Jahrbuch f. Mineralogie*, 1898, II., 192, and Plate XI.

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The cases mentioned by Bauer occur in granites at Point Larue on the Island of Mahé, one of the Seychelle Islands in the Indian Ocean, about latitude 4° 30′ south, and longitude 55° east.

The most impressive examples of the fluting of crystalline rocks that I have ever seen were found in 1911 near the village of Quixadá in the interior of the state of Ceará, Brazil (Plate I.), latitude 5° 5′ south and longitude 19° 20′ west at an elevation of 180 meters above tide. In the vicinity of Quixadá almost every elevated exposure of the granites shows more or less fluting. Only those of which the best photographs were obtained are shown in the accompanying plates. The hills shown in these pictures are from 100 to 225 meters high, that is above their bases. Efforts to get photographs of the fluting about Quixadá have been only partially successful, as may be seen from the illustrations given with the present paper. Horace E. Williams of the Serviço Geologico do Brazil has sent me a photograph of fluted granites in the Serra de Borborema, 25 kilometers south of Campina Grande in the state of Parahyba.

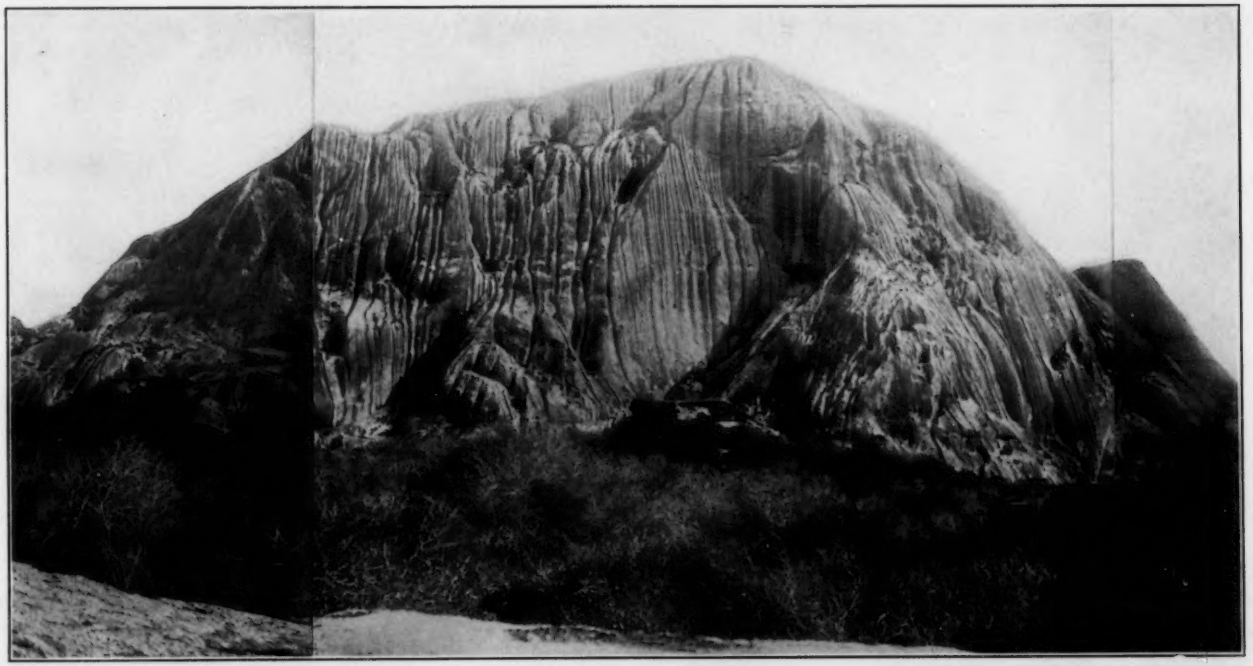
Other cases that have come to my attention occur in the interior of Ceará, and about the famous Itatiáya, the loftiest peak in Brazil, situated in the extreme northwest corner of the state of Rio de Janeiro. Itatiáya has an elevation of 2,994 meters above tide. The fluting of that peak was mentioned to me many years ago by Mr. Derby, the present director of the geological survey of Brazil,[3] but I did not then fully realize the extent and amount of it.

Recently I received from Dr. Carlos Moreira, of the National Museum at Rio de Janeiro, some photographs made by him of the Itatiáya peaks together with specimens of the rocks themselves. Dr. Moreira spent some forty-five days on and about that peak, and though his photographs are small, they are clear, and they are the best we have thus far seen of the fluting in that particular region (Plate II.).

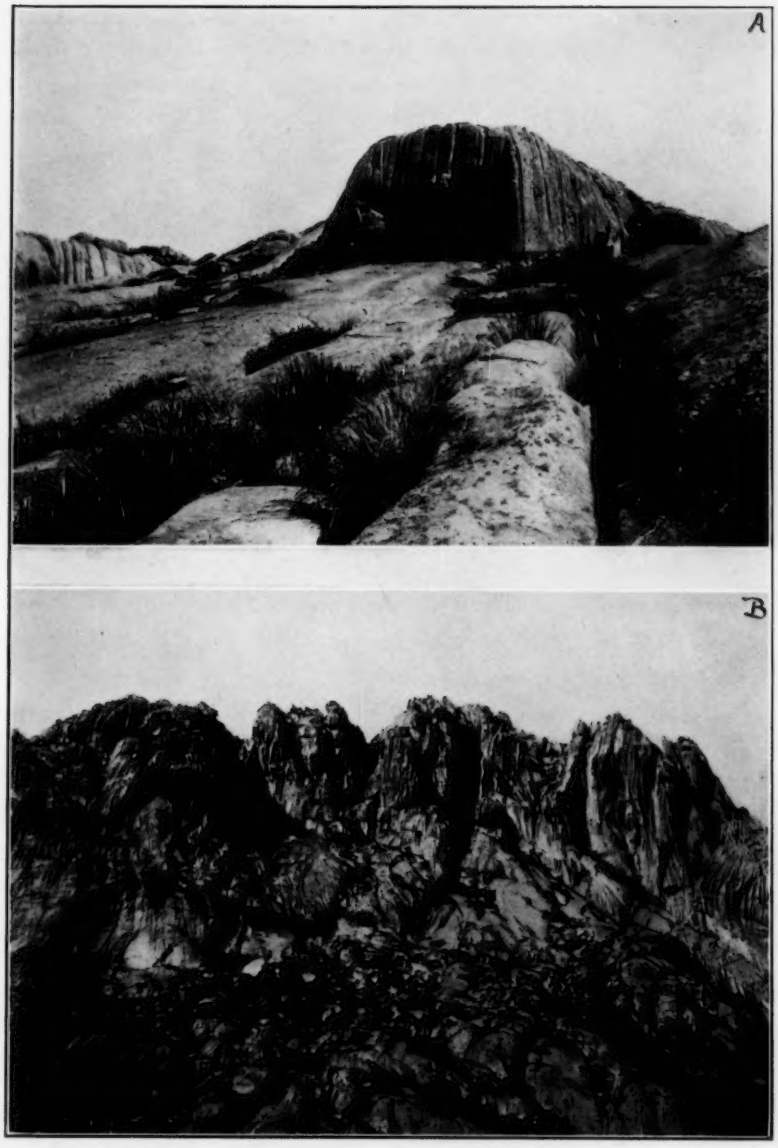
Characteristics of the Fluting of Granites.

In the fluting of limestones there is generally left at the crest of

[3] *Bul. Geol. Soc. Amer.*, VII., 280, footnote.



Serra Riscada near Quixadá, Estado do Clará, Brazil. Height of the hill above its base, 226 meters. Inspectoria de Obras Contra as Seccas, phot., 1911.



Fluted syenite on and about the summit of Itatiáya, State of Rio de Janeiro, Brazil. Carlos Moreira, phot.

the miniature watersheds characteristic sharp, but somewhat ragged, combs of the rock. Between these divides are narrow, round-bottomed furrows or grooves that run down the slopes of the rocks by the shortest routes. These shallow grooves suggest the marks made by the fingers when drawn across a mass of plastic clay or putty. The furrows or grooves in limestone, however, are, as a rule, only an inch or so in diameter; that is the fluting of limestones is not usually on a large scale.

The illustrations given in Dr. Stille's "Geologische Charakterbilder," Heft 10, however, show flutings in limestones of various kinds, and some of these have unusually large furrows.

The fluting of granites and other coarsely crystalline rocks, however, is on a large scale, and the grooves have only a remote resemblance to those on limestone surfaces. The fluted surfaces necessarily appear only where the rock is entirely bare of soil. For the most part the furrows start at the summit of the exposed rock or as near it as possible, and run straight down the rock slopes by the shortest possible routes. Those seen at and about Quixadá reach a maximum depth of nearly two meters measured at right angles to the general surface of the rock masses. This takes no account of the ordinary gullies cut by the larger streams. Instead of having sharp combs separating the drainage areas of the different furrows, the divides or miniature watersheds on the granite surfaces are always rounded. But while the surfaces of the granite rocks are rounded in general outline, they are quite rough, this roughness being caused by the coarse crystals standing out boldly over the entire exposed rock surface. About Quixadá the rocks contain but little quartz, and feldspars are the minerals that produce this roughness of surface.

Caldron-like Pits.

In the Quixadá region the fluted rocks are covered here and there with great rounded caldron-like pits some of which are associated directly or indirectly with the fluting. These pits are shown in some of the accompanying illustrations (Plates III., IV., V.). They are not usually very deep, that is, they seldom exceed a depth of two meters

when isolated, and they reach a diameter of two meters or more, though they are generally not so wide. The fluting sometimes has the appearance of originating in these caldrons, but this seems to be due to the water overflowing and cutting notches in the rims on one side and thus merging the pits and the fluting into each other. In some cases I have seen a series of these pits in a nearly vertical row

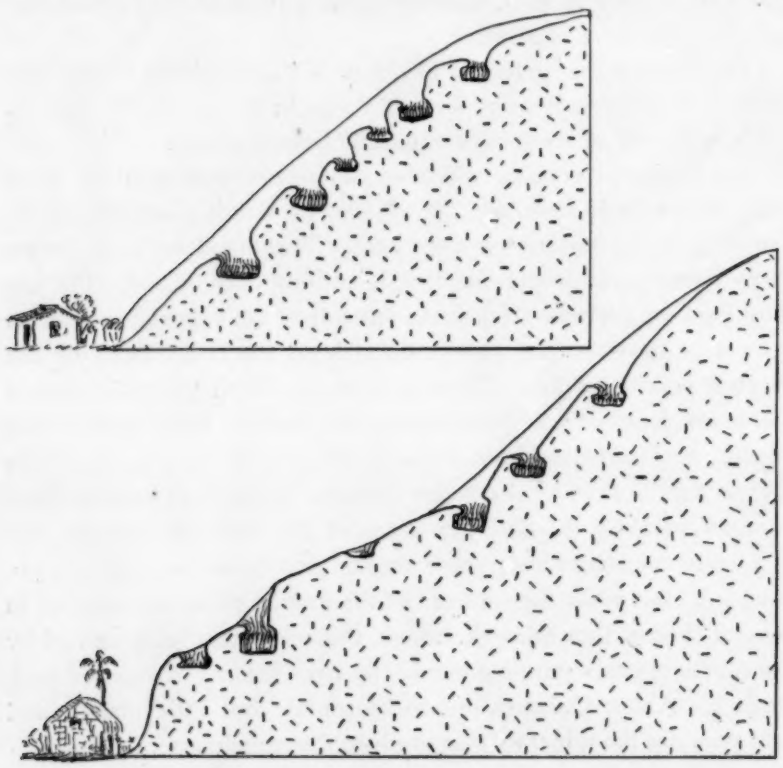
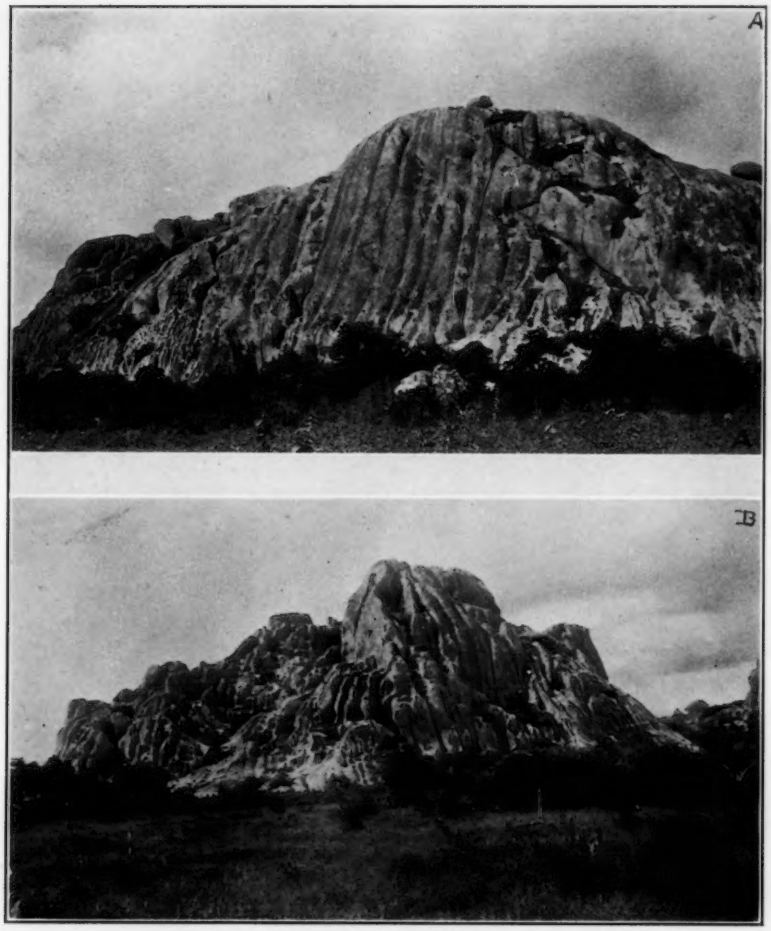


FIG. 1. Composite sections down the pitted and fluted rock surfaces at and about Quixadá showing the general forms of the caldrons.

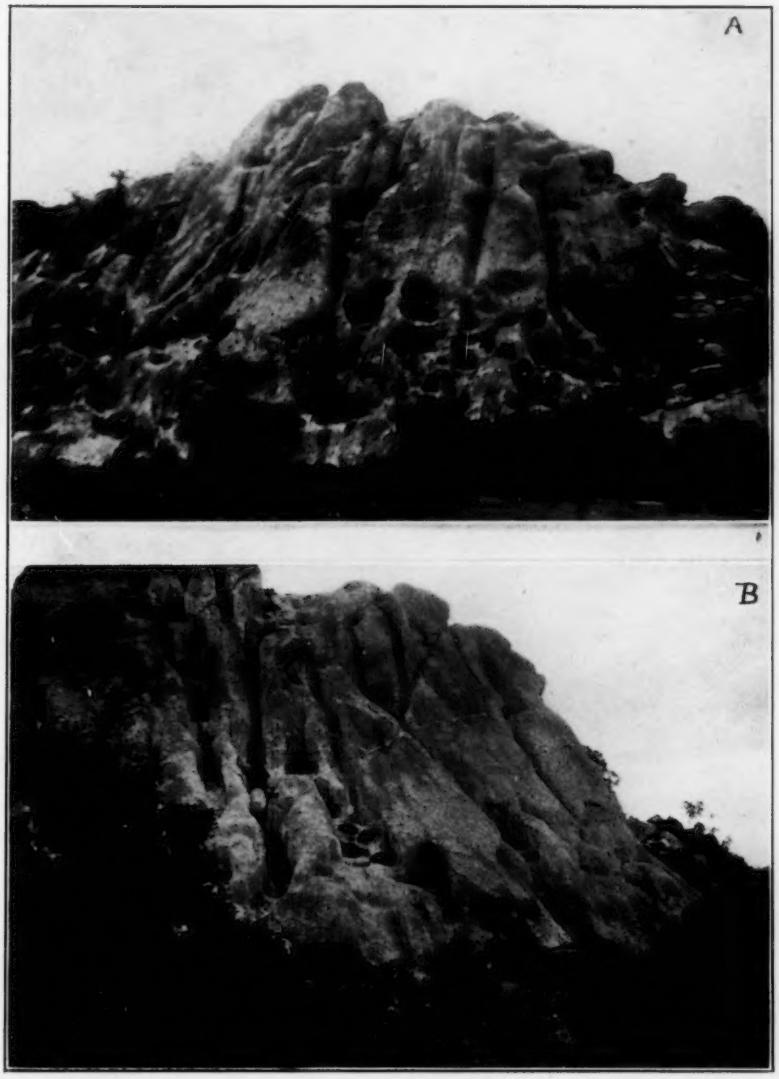
and connected by a furrow that gives the whole the appearance of a great irregular staircase mounting the hill (Fig. 1).

These caldrons are very abundant in some of the rocks, while in others they do not appear at all. They occur on the tops of mountains, hills, or bosses, on the sides and at the bases; they are mostly



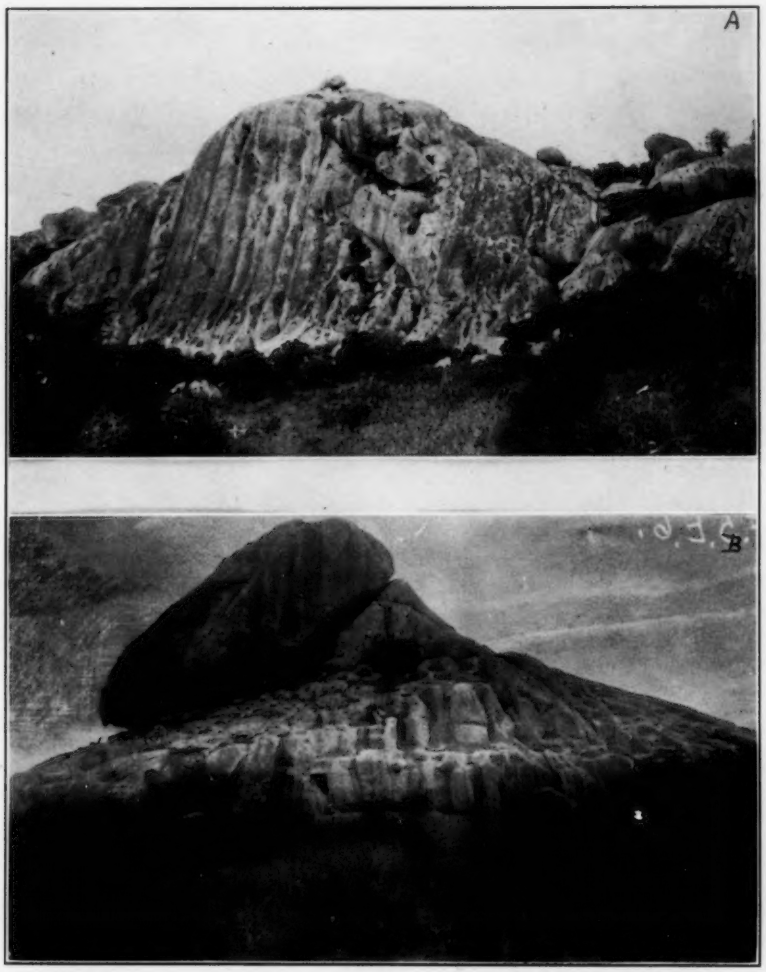
A. Fluted and pitted hills at kilometer 183, near Quixadá, Ceará. Waring, phot., 1912.

B. Fluted and pitted hills at kilometer 183½, near Quixadá, Ceará. Waring, phot., 1912.



A. Pitted syenite east of the railway near Quixadá, Ceará. Waring, phot., 1912.

B. Pitted granodiorite near Quixadá. E. Leib, phot., 1911.



A. Fluted and pitted granodiorite near Quixadá, Ceará. E. Leib, phot., 1911.

B. Pitted granite between the stations of Junco and Quixadá. E. Leib, phot., 1911.

vertical or nearly so, but some of them are also nearly horizontal. At Quixadá they are more abundant on the gentler slopes and especially about the bases of the hills. In Plate V., Fig. *B*, for example, there is a striking difference between the fluted surface in the upper part of the hill and the pitted and fluted surface of the rock about the base of it.

The great rock in the edge of the village of Quixadá is a striking illustration of the combination of pits and of fluting, though the caldrons are the more marked feature of this particular mass (Plate VI., Fig. *B*). The photographs of Itatiáya show the surface to be pitted here and there, but the pits appear to be formed on vertical walls as well as on sloping or flat surfaces (Plate VII., Figs. *B*, *C*).

A good deal has been made of pits or pot-holes in the granites in other parts of Brazil. In Hartt's "Geology and Physical Geography of Brazil," at pages 314–315, is an account of holes observed in granites in the interior of the state of Bahia. Following are the notes of J. A. Allen on the region southeast of the Serra de Jacobina.

"At frequent intervals there were singular holes in the rocks, usually nearly filled with water, to which the inhabitants give the name 'caldeirões.' These 'caldeirões' are of frequent occurrence, but I was unable to learn whether all were of a similar character. Nearly all of the considerable number examined proved to be genuine pot-holes, and some of them were of great size. The largest one I measured was elliptical in outline, eighteen feet long, nine or ten in width, and twenty-seven deep, with smoothly worn sides. Beneath the water that partially filled it there must have been many feet of materials that for ages have been falling into it, so that its whole depth must be much greater than my measurements indicate."

Professor Hartt adds the following as a footnote:

"Mr. Allen tells me that these pot-holes often occur out on the plain, far away from any high land, and that they are sometimes found excavated in the summits of slight bulgings in the plain, or even on the top of a hill, as in the case of the Morro do Caldeirão. These holes must have been excavated by falling water. There is only one suggestion that I can make as to their origin, and that is that they were formed by glacial waterfalls, in the same way as the pot-holes found over the glaciated regions of North America, as, for instance, in New Brunswick and Nova Scotia, where I have had an opportunity of examining them. It is well known that glacial waterfalls, notwithstanding the constant movement of the ice, are very often stationary, and

in the Alps they hollow out enormous pot-holes in the rocks. The lake plain is noted for the small amount of decomposition which has taken place over it, owing, I believe, largely to the fact that it has never been covered by the virgin forest, having always been dry."

The explanation here suggested will be referred to later.

Character of the Fluted and Pitted Rocks.

The fluting of crystalline rocks is not confined to any one particular kind of rock, as was at first supposed, except that they are all massive and homogeneous. Those about Quixadá in Ceará vary somewhat, but they are mostly massive coarse grained, gneissoid granodiorites, and the weathered surfaces, though rounded in outline, are very rough, owing to the feldspar crystals standing out over them in high relief.

The rocks are often more or less jointed, and the joints necessarily interfere with the regularity and extent of the fluting, though they do not prevent it. Possibly abundant jointing may so interfere with fluting as to render it quite inconspicuous.

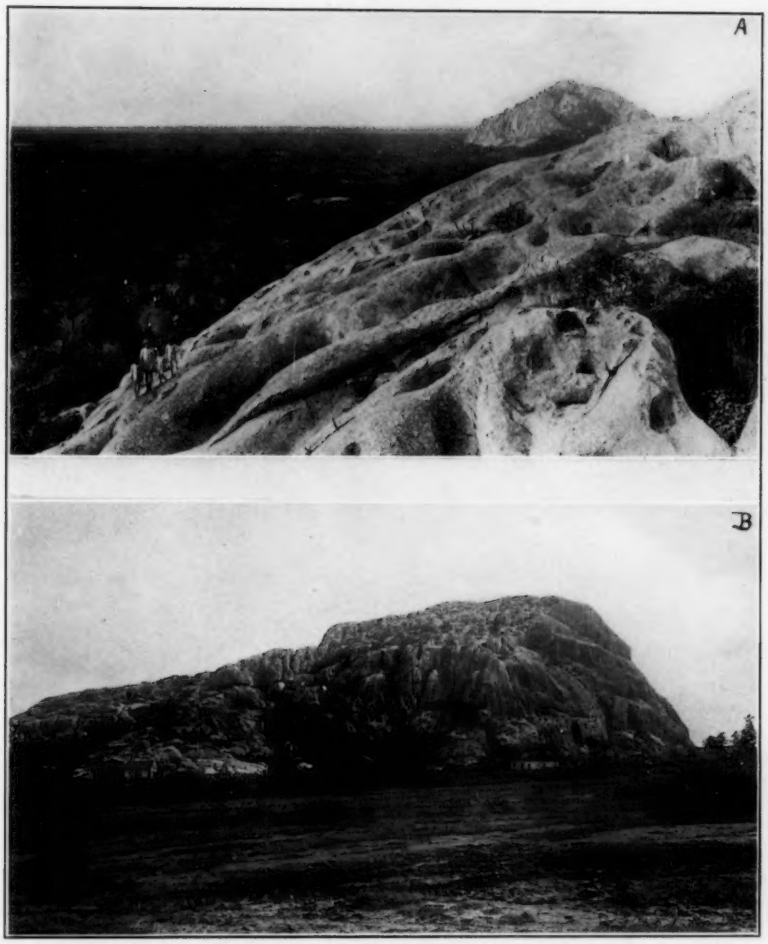
The fluted rocks of the Itatiáya group are massive homogeneous, coarse grained syenites, somewhat jointed, the joint planes having various angles with the horizons, as may be seen in the accompanying illustrations. The Itatiáya syenite is not as coarse grained, however, as the granodiorite of Quixadá.

The fluting mentioned by Bauer in the Seychelle Islands is said to be in granite. The examples seen by the writer in the state of Pernambuco are all in granites.

Origin of the Fluting.

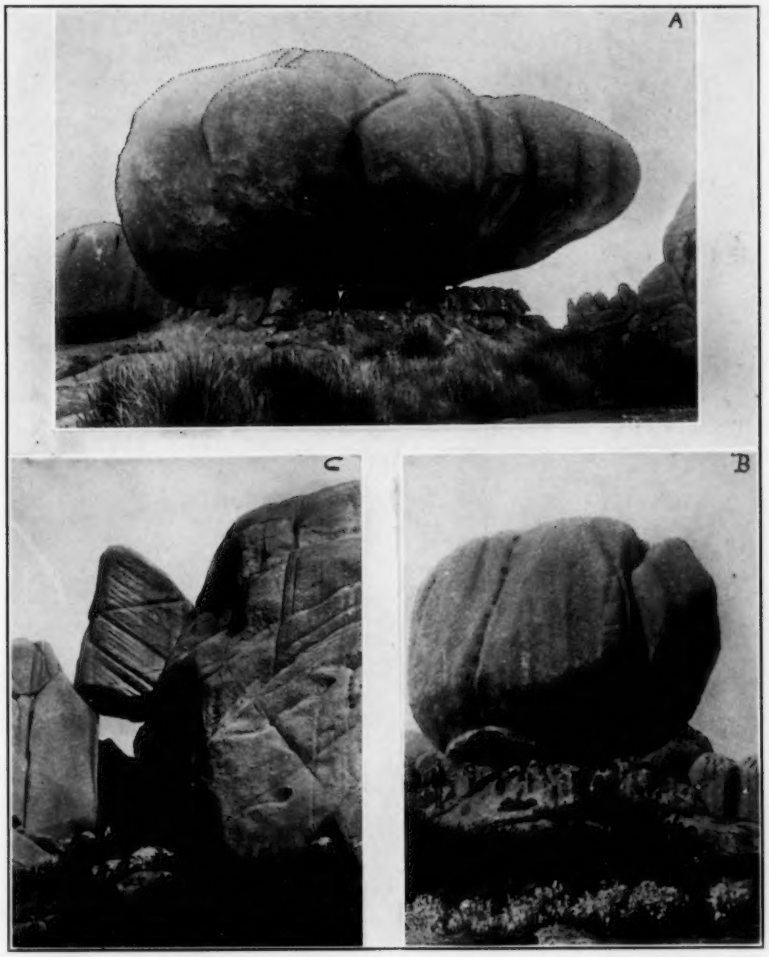
It was supposed at the outset that chemical action over openly exposed surfaces would turn out to be an important factor in the production of the fluted forms. But it does not appear that such action is especially important. It is evident that the rocks are chemically affected by the alteration of the feldspars, but there is no apparent localization of that action in the case of the fluting.

It seems most probable that in the long exposure of these homo-

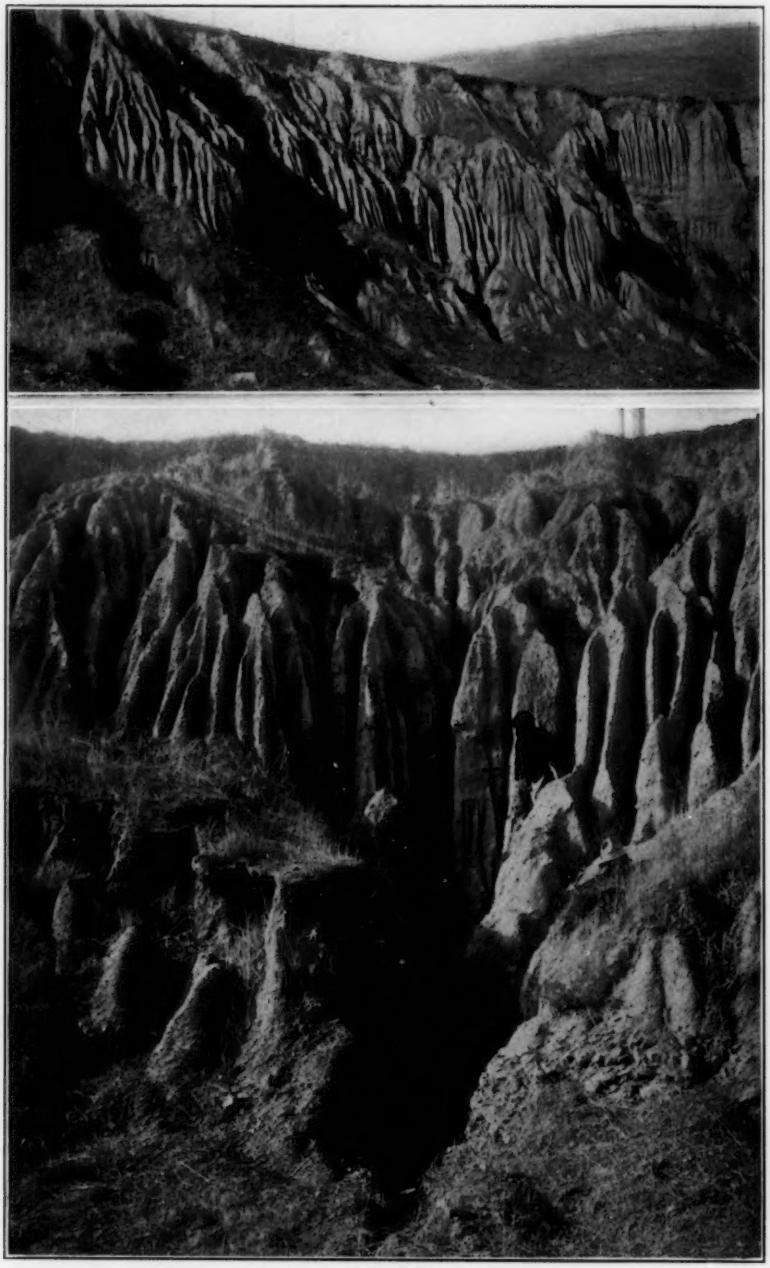


A. Top of fluted hill at kilometer 182½, near Quixadá, Ceará. Waring, phot., 1912.

B. The fluted and pitted granodiorite hill at Quixadá, Ceará. Altitude about 200 ms. Waring, phot., 1912.



Fluted boulders of decomposition in the vicinity of the peak of Itatiáya. Fig. C shows a fluted mass that has been overthrown so that the fluting is no longer vertical. Carlos Moreira, phot.



Fluted banks of sandy clay, San Bruno Mountains, south of San Francisco, Cal. Branner, 1912.

geneous rocks, the water running down the slopes sweeps along mechanically the loosened fragments of the minerals just as it would remove anything else. Channels are necessarily deepened most rapidly where most water flows, and in the process of rock removal, as a whole, the bottoms of these channels always keep in advance of the divides between them. That is, it is a narrow localization of mechanical action by water.

It is especially noticeable that the fluting is a slow process, and this slowness is explained by the fact that each furrow is made by the little water that falls within its own narrow drainage basin.

One may occasionally see in soft sandy clays furrows very similar in form to the fluting of granites. There are some rather striking examples in the San Bruno mountains just south of the city of San Francisco in California. One of the accompanying plates (Plate VIII.) shows two photographs of these particular gullies. These photographs of gullies were made in January, 1912.

The materials of these furrowed banks are sandy clays containing angular and subangular pebbles and rock fragments—apparently soil and other products of the breaking down of the shales and sandstones of the San Bruno mountains. These materials also remind one of the stone-capped earth-columns of the Tyrol, though in the present case the stone caps are wanting.

Such earth-columns are supposed to be the work of the mechanical impact of rainwater. But most of the San Bruno furrows have the appearance of being made, not necessarily by the impact of raindrops, but by the running down of the water that falls on and over the furrowed surface.

Water flowing down from the slopes above cuts the deeper gullies in the face of the bank, but the minor trenches are supplied only by water that falls on the immediate surface.

The even spacing of these furrows is one of their striking features. This is due I presume to the fact that, owing to the rather even surface and the evenness of the water supply, there is usually nothing to enable a channel to gain on its neighbors.

The Origin of the Caldrons.

The suggestion of Hartt quoted on a preceding page in regard to the glacial origin of caldrons or pot-holes in the interior of Bahia must be set aside as quite out of the question, either for the ones in Ceará or for those in Bahia.[4] There is absolutely no evidence of Pleistocene glaciation in Brazil.[5] The pot-holes mentioned by Hartt and Allen in the interior of Bahia, in every case with which I am acquainted, have been cleaned out by man for the purpose of using them for water storage in times of drouth. They have but little in common with the caldrons referred to in this paper.

The Quixadá pits are in process of development, and they are evidently therefore to be explained by agencies now in operation. Aside from the openly exposed bare surface of a coarsely crystalline homogeneous rock, the factors that enter into the problem appear to be: The slope of the surface, the localization of incipient depressions, disintegration and chemical alteration of the rock forming minerals by the action of rainwater aided by organic and other acids, the concentration of rainfall, and the mechanical floating away of the disintegrated and finely divided minerals.

It seems probable that the original location of the incipient caldrons is purely accidental. Once begun, however, the standing water attacks the constituent minerals of the rock in the bottom of the pit. It is quite noticeable that in the great majority of the caldrons, perhaps in all of them, the walls are somewhat overhanging. This overhanging is due to the fact that once a pit is started, the water standing in it tends to moisten and affect a widening surface.

As soon as a depression is deep enough to retain some of the rainwater, plants begin to grow in it, and insects are drowned in it, and as these things decompose the organic acids thus produced enable the water to attack the minerals more readily.

The concentration of the rainfall of the region causes the pits to be filled with water for only a part of the time. The rest of the time the pits are dry or they are only moist on the bottom.

It has been suggested that deflation may be an agency in the for-

[4] Hartt's "Geology and Physical Geography of Brazil," pp. 314–315.

[5] "The Supposed Glaciation of Brazil," *Jour. Geol.*, I., 753–772.

mation of these caldrons. In my opinion deflation may be important in the early stages of excavation, when the depth does not prevent the wind from blowing away small loose fragments of the minerals, but when a pit is a meter or more in depth and a meter in width it seems highly improbable that the wind is a factor of any importance in the direct removal of materials, though it may be indirectly important enough in the bringing of plant seeds or spores.

The things that seem to me competent to account for the removal of the disintegrated minerals are suggested by the dark lines that run down the rocks from the notches in the lips of all of the caldrons. These dark streaks are made by overflowing water.

When water stands for some time in the pits it becomes covered by low forms of plant life, apparently freshwater algæ for the most part. When in time the water dries up this material is left spread over the bottom where it packs together, a sticky fibrous mass clinging to and closely enwrapping whatever lies in the bottom of the pit. In time the rains come again and the pit is filled to overflowing, the matted masses of algæ are floated to the top and carried over the edge of the caldron, taking with them some of the mineral fragments from the bottom of the pit. The rapid growth of vegetation in such waters is greatly facilitated by the hot climate, while the hot dry air and the high winds quickly dry up the waters when once the pits are filled by the rains. The peculiar concentration of the rainfall at Quixadá likewise hastens this natural process of excavation.

Still more important in most instances is the stirring of the materials in the bottoms of the caldrons by the inflowing water. The mud in the bottom being thus stirred by the water pouring in, a great deal of the finer material is carried out when the pit is full and overflows its lower lip. It must not be supposed, however, that the water flowing into the caldrons is of sufficient volume to whirl the coarse materials and thus grind out the rock. This is far from being the case. I found no evidence of any such mechanical wear on the insides of the pits. They are all uniformly rough within.

When the pits are shallow, however, and are so far down the slopes that the water enters them with a rush it is readily imagined that all or most of the finer materials must be swept over the rim. Some of the forms suggest that old and deep caldrons have from

time to time been obliterated by the breaking down of their lower lips.

Fortunately we have the records of the rainfall taken at Quixadá from 1891 to 1906.[6] These records show that during those fifteen years the total precipitation was 10,711 millimeters. Distributed by months, the greatest rainfall was in February, March, April, and May when it reached an average of 134 millimeters a month; the minimum fell in August, September, October, and November with an average of 17 millimeters per month.

These figures taken alone, however, do not give a clear idea of the climatic conditions in the semi-arid region about Quixadá. An important fact that bears directly upon the question of the origin of these caldrons is that the rains are frequently torrential while they last, even during the dry season, and that they are often followed by periods of drouth during which the hot dry atmosphere quickly takes up the water filling the caldrons. For example, the table of rainfall shows that in October, 1894, there was a precipitation at Quixadá of 96 millimeters in a single day, and that too in the dry season. In December of the same year 95 millimeters fell in two days; in July, 1904, the rainfall was 147 millimeters in two days. In the last case this heavy rain was followed by nearly five months of complete drouth. But even in the absence of long drouths, the rapid evaporation and high winds and high temperatures would empty one of these caldrons in a short time. The temperature at Quixadá[7] in 1897 ranged from an absolute maximum of 36.2° C. to an absolute minimum of 22.1° C.

Statistics dating back to 1711 bear out the generally accepted fact that the interior of Ceará is a region of frequent drouths. In the 189 years from 1711 down to and including the year 1900 it is claimed that there have been thirty-one years of drouth.[8] But even the years of drouth may have had rain enough to overflow the cal-

[6] Thomaz Pompeo de Souza Brasil, "O Ceará no começo do Seculo XX.," Fortaleza, 1909, p. 330.

[7] F. M. Draenert, "Zum Klima des Staates Ceará, Brasilien," *Meteorologische Zeitschrift*, April, 1903.

[8] Raymundo Pereira da Silva, "O Problema do Norte." Rio de Janeiro. 1907, p. 7.

drons several times without there being enough to answer the purposes of the planters and cattle growers.

It may be worth noting also that in dry seasons, and as long as the water lasts, birds and other animals flock to these caldrons to drink.

The total result of the alternation of rain and drouth must be a frequent filling and emptying of the pits, a frequent stirring up of the fine materials in the bottoms of the pits, and its removal in mechanical suspension by the water overflowing the lips of the caldrons.

These facts also suggest why the caldrons are most abundant about the lower slopes rather than on the crests of the hills: there is a larger run-off, and consequently a more frequent and a more vigorous disturbance of the water in the pits.

The horizontal pits occasionally seen in vertical rock walls are evidently not made in the same way as the vertical pits formed in flat or sloping surfaces. The latter seem to be due to the alternate absorption and evaporation of water much as fret-work is formed over the surfaces of porous sandstones by the prying off of sandgrains. Some remarkable cases of this kind are known in the interior of the state of Bahia in Brazil. Instances of this sort are now being studied and no further mention of them need be made at present.

Conclusions

The fluting and pitting of coarse grained crystalline rocks appears to be confined to tropical countries, and to massive, homogeneous rocks openly exposed.

The grooves that make up the fluted surfaces run down the rock faces by the shortest possible courses, and are made by the small amount of water that falls upon and flows down the fluted surfaces themselves. In other words there are no strong streams flowing across fluted surfaces whose waters are gathered over a wide area.

Fluting seems to be confined to steep slopes. The angle of such slopes cannot be stated, but in the cases observed it usually was forty-five degrees or more.

The process of fluting is partly chemical and partly mechanical

and physical. As a whole the process is necessarily a slow one. The localization of the run-off leads to an approximately even spacing of the small streams and consequently to the even spacing of the fluting where it appears over a broad surface. Somewhat similar erosion forms are to be seen occasionally in homogeneous sandy clays, though owing to the character of the materials the latter are cut rapidly.

Though fluting seems to be confined to tropical countries, it is worth noting that the temperature on the Serra do Itatiáya in Brazil, where fluting is very marked, often falls below freezing. Evidently some freezing does not interfere with fluting.

Caldron-like pits are associated with fluting, and occur chiefly on slopes not so steep as the fluted ones. They are most abundant on the lower parts of the bare rock surfaces. They are formed by water dissolving and disintegrating the minerals, and by the inflowing waters mechanically stirring and floating the finer particles over the rims of the basins. The chemical action of the water in the pits is hastened by the decay of plants and other organisms that live and die in the water left standing in the pits by the rain.

Exfoliation is not a prominent feature of the fluted and pitted masses. Indeed exfoliation hardly occurs at all in such places. Disintegration goes on rapidly, but it attacks the entire surface pretty evenly. The feldspars seem to resist weathering better than the accompanying minerals, at least the feldspars are left standing out in high relief over these surfaces. In time the mere heating and cooling of the feldspars breaks them up, and they are washed off by the torrential tropical rains as angular fragments or they are blown off by the winds.

The absence of talus about the bases of these fluted and pitted hills is very striking. Indeed there are quite as many boulders on the summits and sides of the hills as there are about their bases. This seems to be due to the even attack of disintegration over all surfaces, and to the fact that there is no freezing and thawing to chip off the upper surfaces of hills and rocks and to pile up the fragments at the bases of the slopes.

STANFORD UNIVERSITY, CAL.

ON THE PROSPECT OF OBTAINING RADIAL VELOCITIES BY MEANS OF THE OBJECTIVE PRISM.

By FRANK SCHLESINGER, M.A., Ph.D.

(*Read April 20, 1912.*)

Among the many problems that confront the workers in stellar spectroscopy at the present time, three stand out by reason of their importance. First, the classification of stars by means of their spectra. Second, the determination of absolute radial velocities for the purpose of determining the sun's way, and the relation between stellar spectra and stellar motions; and of throwing light upon various hypotheses regarding star-streaming. Third, the determination of the orbits of spectroscopic binaries.

In the second and the third of these problems the need of extending our determinations of radial velocities to faint stars has become very pressing. At the present day a comparatively large number of observatories are equipped with apparatus that, without involving unduly long exposures, will yield radial velocities for stars down to the fifth magnitude; but what is greatly desired is an extension to stars at least as faint as the eighth magnitude. It is futile to hope to attain such an extension by erecting more powerful telescopes and by attaching to them slit spectrographs of even the most approved design. Experience has amply shown that in work of this kind the gain that comes with increasing the size of the telescope is only very slight. The principal reason for this is the loss of light at the slit, which under favorable circumstances in the case of telescopes of the largest size must frequently be as much as ninety per cent.; and under certain atmospheric and instrumental conditions this percentage of loss may be considerably increased. With smaller telescopes the loss of light at the slit is not so serious, and for this reason, as well as for others, it is a fact (to cite somewhat extreme cases) that the spectrographs attached to certain telescopes having

apertures from twelve to fifteen inches have proven nearly as efficient for the determination of radial velocities as those attached to telescopes of two or three times their aperture.

If, therefore, we are to seek any considerable extension of these observations to fainter stars, we are forced to turn to the objective prism, the great advantage of this form of spectroscope being its economy of light. Few slit spectrographs now in use utilize more than one per cent. of the light that falls upon the objective of the telescope to which they are attached. With the objective prism, as much as twenty-five per cent. may easily be realized with a proper choice of materials in the objective and in the prism, and providing also that the thickness of the prism is not too great. Furthermore, with the slit spectrograph we secure the spectrum of only one star at a time, whereas with the objective prism all the stars in a considerable area of the sky impress their spectra upon the same plate. On the other hand, the difficulty of securing points of reference from which the shifts in the lines may be measured has thus far proved an insurmountable obstacle in the way of obtaining even fairly accurate velocities by this means.

Spectra produced by diffraction gratings are nearly normal; that is, the distance between any two lines is approximately proportionate to their difference in wave-length. In such spectra the shift due to velocity is greater for lines of greater wave-length. Consequently, the spectrum is lengthened if the star is receding from us and is shortened if the star is approaching. On the other hand, spectra produced by prisms are far from being normal, lines in the region of greater wave-length being crowded together, while those at the violet end are more widely separated. In this case, shifts due to velocity become reversed in their relative amounts, being now greater for lines of shorter wave-lengths. Prismatic spectra are accordingly shortened for receding stars and lengthened for those that are approaching us. We see, then, that the lengths of both prismatic and diffraction spectra are changed by radial velocity, and accordingly the latter can, theoretically at least, be found by measuring the distance between two lines widely separated in the spectrum.

The possibility of determining velocities in this way seems first

to have occurred to Pickering, who suggests and dismisses it in a single sentence, on page xxi, Volume 26, *Annals of the Harvard College Observatory*. A few years later the same method was independently proposed in a somewhat different form by Orbinsky[1] and also by Frost.[2] None of these suggestions seems to have been taken up by astronomers, and so far as I know there is no record of any actual experiment dealing with the length of spectrum from the point of view of radial velocity.

Whatever may have been the promise held out by these proposals when they appeared twenty years ago, I should like to point out that their chance for leading to valuable results may be greatly increased by the use of modern photographic plates. Recently several investigators have shown us how to prepare plates that are sensitive throughout a far greater range in wave-lengths than was hitherto the case. Formerly, only the region to the violet side of the F line (λ 4,860) could be photographed without necessitating very long exposures; but now we have at our disposal comparatively rapid plates that will yield spectrograms of nearly uniform density from the K line at λ 3,933 to the D lines at λ 5,895, or even to the C line at λ 6,563. With former spectra the shift in the lines in the violet region could be ascertained by referring them at best only to lines in the neighborhood of λ 4,800, which themselves share the same shift to a considerable extent. But the yellow and red portions are so closely crowded in prismatic spectra, that lines in this region would show very little shift due to velocity, and hence would form excellent points of reference for lines in the blue and violet.

To carry out this plan, an ordinary objective, whether corrected for photographic or for visual rays, would not answer, since it is necessary to have in focus at the same time lines in both regions. Cooke in England has successfully put upon the market an objective,[3] made up of three different kinds of glass, which brings into good focus the entire range of spectrum from λ 3,800 to λ 6,000. An objective of adequate aperture of this type would serve the present

[1] *Astronomische Nachrichten*, **138**, 9, 1895.
[2] *Astrophysical Journal*, **2**, 235, 1895.
[3] Designed by Mr. Dennis Taylor.

purpose fairly well. It would be still better to design an objective with this specific application in view and to bring into focus the two regions say from λ 3,900 to λ 4,500 and from λ 5,900 to λ 6,600, without paying much attention to the intermediate region, from λ 4,500 to λ 5,900.

It would be quite possible to use a reflecting telescope for this purpose. But as compared with a refracting telescope the reflector seems to be less promising for two reasons: first, because of the change in the focal length with change of temperature; and, second, because of the harmful effect of any change in the inclination of the mirror. Thus, if one edge of a mirror whose aperture is one tenth its focal length should be tilted with respect to the other edge by only one micron, the lines in the spectrum would be shifted by twenty times this amount, a quantity that is of the same order as the shift due to velocity. In refracting telescopes the effect of a slight tilt in the objective is of no consequence whatever.

With the objective prism it is difficult to make long exposures that will show sharp spectra. This is chiefly because the refractive index of glass varies rapidly with the temperature and the amount by which the rays of light are deviated is thus continually changing if the prism is in the open air. Observers with slit spectrographs have long been aware of the necessity of guarding their prisms against changes of temperature, and have learned to surround them with cases within which the temperature is artificially kept from fluctuating. As I pointed out a few years ago,[4] there is no reason why a similar device should not be used in connection with objective prisms. In this case, the light from the star should first be admitted through a window of optically plane parallel glass, whose aperture is the same as that of the prism and the objective. This window should form part of a temperature case enclosing the whole camera, including the prism, the objective and the plate-holder. The case can then be maintained at constant temperature in the usual way.

Even with these precautions it would be well, in the experimental stages at least, to calibrate the prism frequently by means of stars whose velocities are known from observations with slit spectro-

[4] *Science*, 30, 729, 1909.

graphs. More than a thousand such stars are available at the present time and in a few years this number will be at least doubled; so that there should never be any great difficulty in finding a suitable test object close at hand. The process of observing would then perhaps consist of an exposure on a star whose velocity we wish to determine, immediately followed in each case by an exposure (made on the same plate close to the first) on a neighboring star whose velocity is already known. The difference of the lengths of these two spectra is then to be measured, converted into units of kilometers per second and applied to the known velocity.

A quarter of a century ago the suggestion was made by Pickering, in connection with his experimental work for the Draper Memorial, that radial velocities could be determined from objective prism spectra if some absorptive medium could be found that would produce one or more narrow and sharp absorption bands. If such a substance were interposed at any point in the spectrograph, or indeed anywhere between the star and the plate, the resulting spectra would also show these bands in positions not affected by the velocity of the star, and would thus offer a beautifully simple method for determining velocities. Pickering made a search for a substance with this very desirable quality, but at that time did not succeed in finding a satisfactory one. Recently, however, he suggested this subject to Professor R. W. Wood, who after experimenting with various compounds has proposed neodymium chloride for this purpose. This substance introduces into the photographic region of the spectrum a number of absorption bands. One of these, at λ 4,272, is sharp and fairly narrow, having a width of about three angstroms, a quantity that corresponds to a velocity of about 200 kilometers a second. This substance seems, therefore, to offer a method for measuring the velocities of certain stars with a moderate degree of precision. Just how accurately this can be done, we must wait for actual experiments to tell us; and such experiments are under way in at least two observatories. There can be little doubt that an accuracy represented by a probable error of not more than ten kilometers can be attained in this way. This Pickering-Wood method is hardly applicable to any but stars of the A and B types. In stars

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of the F type and beyond, the neodymium line or band at λ 4,272 becomes involved with lines that are proper to the star itself, and accurate settings upon it become impossible.

A number of other suggestions have been made for utilizing the objective prism for determining velocities, but I shall stop to consider only one of these. Like the two proposals that we have already described, this method owes its origin to Pickering,[5] who seems to have studied this problem to good purpose long in advance of any other astronomer. Let us suppose that we have secured by means of the objective prism a photograph showing the spectra of a number of stars in the same region, and that the prism has been so oriented that the violet end of each spectrum is toward the north. Suppose further that we have measured accurately the position of the K line in each spectrum. From these measurements we might compute the relative declinations of the stars, but these declinations would be in error by a slight amount on account of the unknown radial velocities of the stars. Thus a star that is approaching us would have its K line shifted toward the violet end, or in this case, toward the north, and the computed declination would be too great. Let us then secure another photograph of the same region with the prism reversed, so that now the violet end of each spectrum is toward the south. The approach of a star would as before shift its lines toward the violet, which is, however, now toward the south. We should therefore derive a relative declination for the star that is as much too small as it was too great in the first instance. It is obvious, then, that the measurement of such a pair of plates would theoretically give us the data from which the relative velocities of all the stars on the plate might be inferred. Pickering further proposed that the prism be reversed by simply reversing the telescope on its equatorial mounting, and that the comparison of the two plates could be facilitated by taking one of them with the glass side outward. The plates could then be put film to film and the measurements would become differential.

Although the theory of this method is simple enough, its practical

[5] Harvard College Observatory Circulars, No. 13; see also *Astronomische Nachrichten*, 171, 137, 1906.

application is a matter involving serious difficulties. A number of modifications have been proposed with a view to obviating one or another of these difficulties. Thus Stewart[6] suggested that, instead of making exposures upon two different plates, two objectives and two oppositely placed prisms be employed for making two simultaneous exposures side by side upon the same plate. The plate would then have to be inclined equally to the two incident beams, and, under ordinary circumstances, it would be possible to secure only one pair of spectra upon each plate. Another modification is that due to Comstock,[7] who proposed that the two halves of the objective be covered by two prisms having their refracting edges turned toward each other. These prisms are to be compound and of the "direct-vision" variety, so as to yield for each star a pair of spectra in close juxtaposition. Here, however, we encounter the difficulty of securing prisms of sufficient size, for prisms of this description would have to be very thick in order to give spectra of sufficient dispersion. The present writer has suggested still another modification,[8] in which the two plates are taken simultaneously by means of two independent (but similar) cameras and prisms, both being enclosed in a constant temperature case provided with two suitable windows of plane parallel glass.

The advantages of securing the two photographs at the same time are two-fold; first, this obviates any necessity for considering refraction, a very bothersome matter when large fields are in question. Second, the so-called guiding error is eliminated. Whether the telescope is driven entirely by clockwork, or whether the observer attempts to secure more perfect guiding by introducing slight corrections by hand, the spectra will still wander a little from their mean positions and the place at which an observer will bisect a line in the spectrum will depend somewhat upon the nature of the guiding. If, however, the direct and the reversed spectra are secured simultaneously, the guiding error will be the same for both and will have no effect upon the derived velocity.

In this method of determining velocities there remains a difficulty

[6] *Astrophysical Journal*, 23, 396, 1906.
[7] *Astrophysical Journal*, 23, 148, 1906.
[8] *Science*, 30, 729, 1909.

more serious than any that we have mentioned. This is the distortion of the field due to the presence of the prism. Let us suppose that there were in the sky a row of stars in the same right ascension and equally spaced in declination. Let us photograph the spectra of these stars with the help of an objective prism whose refracting edge is parallel to the equator. Then, quite apart from the effect of radial velocity, the spectra would by no means be equally spaced upon the plate, the intervals on one side of the center being all too small, and those on the other side all too great. When the prism is reversed, those spaces that were too large are now too small and *vice versa;* so that the distance between the two spectra of the same star depends upon its declination. I have computed this double distortion for a spectrograph whose dimensions are such as one would choose for this work, and have found it to amount to two millimeters at a point only two degrees of arc from the center. This quantity is about one thousand times as great as the accuracy that an observer would hope to attain in his measurements, so that it is readily seen how intimately he would have to become acquainted with his prism in order that he might apply this very large correction within the limit of accuracy that the case demands. Furthermore, there is an additional distortion of nearly the same size in the other direction. That is, if we could photograph a row of stars on the equator, their spectra on the plate would not appear in a straight line, but would lie in a curve that is approximately a parabola with its convex side toward the refracting edge of the prism.[9] If, therefore, the prism is reversed the curvature of this line is also reversed, and when the two plates are compared we again have a double distortion, depending now (in the position of the prism that we have imagined) upon the star's right ascension. It is worthy of remark that these distortions are smaller in the design proposed by Comstock than in any of the others. Furthermore, if we confine our attention to a single pair of spectra in the axis, as in Stewart's suggestion, these distortions do not enter at all.

We see, then, that the obstacles in the way of the practical appli-

[9] It is this same distortion that causes the curvature of the lines upon a slit spectrogram, the formula for which is given by Ditscheiner in the *Sitzungsberichte der Math. Klasse der k. Akademie zu Wein,* 51, part 2, 1865.

cation of this method are undoubtedly serious; nevertheless, they do not appear to be of the character that patience and perseverance on the part of a skillful observer will not overcome.

If the objective prism is ultimately to be used for determining velocities, it would be a great advantage to be able to utilize the full apertures of modern telescopes without necessitating objective prisms of corresponding size. In the case of reflecting telescopes, this might be done by replacing the flat secondary (of the Newtonian form) or the hyperboloid (of the Cassegrainian form) by a convex paraboloid, with its axis and focus coincident with the axis and focus of the primary mirror. The beam of light reflected from such a secondary would be a parallel one, contracted to perhaps one fourth or one fifth the diameter of the original beam. This reduced beam could then be made to pass through an objective prism of moderate size. Similarly, in the case of refracting telescopes, a diverging lens might be placed in the position that the correcting lens usually occupies when the telescope is to be used with a slit spectrograph.[10] This diverging lens can be so designed as to make the emerging beam of light parallel in any portion of the spectrum desired. For practical reasons it would not be advisable to contract the original beam too much; or in other words, to put the converging lens too near the focus of the visual or the photographic objective. In the case of reflectors, too, though for not quite the same reason, the paraboloid should not have too small an aperture and should not be placed too near the primary focus.

In conclusion, it seems to me that the prospect of obtaining radial velocities by means of the objective prism is good enough to warrant a trial of all three of the methods that have been reviewed above. If I were asked which of the methods seemed to me the most promising, I should say that the one which makes use of neodymium chloride would probably lead to immediate results, if we are to remain satisfied with a moderate degree of precision; but that the method which is concerned with the length of the spectrum might ultimately be developed to give considerably more accurate results.

ALLEGHENY OBSERVATORY,
ALLEGHENY, PENNSYLVANIA.

[10] Compare with the paper by Wadsworth, *Astrophysical Journal*, 16, 12, 1902.

THE HISTORICAL VALUE OF THE PATRIARCHAL NARRATIVES.

By GEORGE A. BARTON.

(*Read April 17, 1913.*)

Since the birth of the sciences in the nineteenth century, knowledge has been revolutionized and enlarged in every department. The effect of the creation of the historical and social sciences is as marked in this respect as that of the natural sciences. The account which the records and traditions of a country give of its history is found to begin with mythical stories, which gradually give place to legends and later emerge into sober history attested by documents, which, if not contemporary, date from a time so near to the events, that their testimony, when tested by general considerations, may be accepted. The scientific method applied to ordinary history is generally accepted quietly by the public, which is usually grateful for the clearer vision of past events which it affords.

It has been inevitable, that in the general progress of knowledge the scientific method should be applied to all existing records, sacred as well as to so-called profane. A part of the movement of modern knowledge consists, accordingly, of the application of the scientific method, generally known as the higher criticism, to the records in the Bible. The application of this method has resulted in the division of scholars into three camps: (1) there are the sincere, conscientious, open-minded, reverent scholars, who believe in the scientific method, who see that the Biblical records cannot be rightly exempted from scientific treatment, and who go about the work with reverence and sanity; (2) there are the reactionaries, who are unable to believe that any Biblical narrative can ever have had any other significance than that which they have always attached to it, and who spend their efforts endeavoring to prove, often by the flimsiest arguments from supposed archaeology, that every Biblical narrative must

be taken by the historian at its face value; (3) there is the mythological, or pseudo-scientific school, which has become enamored of the scientific method from afar, but has never undergone the training in judgment necessary to the application of scientific principles. The members of this school fall into two groups. There are those who, like Winckler, dissolve Solomon and everything before him into forms of Babylonian myths, while others, like Jensen and Zimmern, resolve most of the Biblical characters into myths. Under Jensen's touch every important character of the Old Testament and Apocrypha, as well as Jesus and Paul, become simply forms of the myths of the Gilgamesh epic. In view of the division of scholarship into these three camps, it is clear that a scientific student of history must take his stand with the first group. He cannot refuse to use the scientific method upon sources simply because they are sacred, nor can he exercise the liberty of dissolving into myth events attested by documents that are nearly contemporary with the events described.

The historical student of the sacred records finds, perhaps, his most difficult task the proper appraisement of the patriarchal narratives. Scientific criticism has shown that the records of these narratives have been drawn verbatim from three documents, the earliest of which dates from the ninth century B.C. and the latest from the middle of the fifth pre-Christian century. The demonstration of this is so convincing that it has won the consent of nearly all the scientific experts. There is probably no hypothesis concerning any modern science which commands so nearly the assent of all who can rightly be called experts in the subject as the so-called Graf-Wellhausen hypothesis of the origin of the Pentateuch. The public is sometimes deceived by the cries of those whose hopes are greater than their knowledge; but were the Graf-Wellhausen hypothesis a person, it might adopt the words which Mark Twain is said once to have cabled from Europe to a friend: "The report of my death is greatly exaggerated." The historical student of the patriarchal narratives must, then, take the Graf-Wellhausen hypothesis as his starting point. But let him follow the sound historical maxim and prefer the testimony of the earliest document, he is still in perplexity, for the oldest document, the so-called J document, is at least

three hundred years later than Moses. It is as far removed from Moses as the translators of the Authorized Version are from us, and further removed from Abraham than we are from Columbus and Martin Luther.

The historian may obtain a clue to guide him in his perplexity from a study of Genesis, ch. 10. For example, Gen. 10: 6 states that the sons of Ham were Cush, Mizraim, Put and Canaan. Cush here is the Egyptian *Kesh*, or Nubia. Mizraim is simply the Hebrew word for Egypt. Put is the *Punt* which figures so largely in Egyptian history—the country to the far south whence so many expeditions were sent and from which myrrh, ivory and pigmies were brought. Canaan is the well-known tribe or group of tribes from which the Phœnicians were developed, which also inhabited Palestine and gave it one of the names by which it is still called. It is clear that these names represent, not individuals, but personified tribes or nations. Take Egypt, for example. We now know the outlines of its history back to about 5000 B.C. At that time it consisted of forty-two distinct tribes, who lived so long in separation from one another that their animal totems persisted as the representatives of the gods of the different nomes down to the Roman period. Perhaps as early as 4000 B.C. these nomes, often at war with one another, had been united into the two kingdoms of upper and lower Egypt, but these were not united into a single monarchy until the time of Mena, about 3400 B.C. It is simply impossible that these forty-two tribes were descended from one man. Their gods, customs, sacred animals, and warlike emblems were all different. The further back we push our knowledge of Egypt, the more its constituent parts ramify into a congeries of unrelated atoms. It is only from the point of view of later times that it can be spoken of as one entity. The Biblical writer has accordingly personified a nation. What can be proved for Egypt can also be proved in lesser degree for Nubia.

If now other parts of the chapter be explored the names of many nations and countries appear. Gomer (v. 2) is the *Gamir* of the Assyrians, the Cimmerians of the Greeks; Madai is the Medes; Tubal and Meshech, the tribes *Tabalī* and *Mushkī* of the Assyrian

inscriptions. Javan is the *ων* of *ἴωνες*, the Ionians. Elisha (v. 4) is the Alashia of the El-Amarna letters, or the Island of Cyprus; Kittim, the *Kiti* or *Kition*, on that island. Tarshish is Tartessos, the Phœnician mining and trading camp in Spain. Similarly in v. 22 Elam, Asshur and Aram are clearly the names of well known countries. In v. 26 most of the persons mentioned are known to be tribes or towns in south Arabia. In v. 15 it is stated that Canaan begat Zidon. Zidon is the city. Its name means "fishing." The name was not derived from a man, but from an industry.

We derive from this chapter, then, partly composed of J material (ninth century) and P material (fifth century) the general principle that patriarchal names are probably not personal names, but are personified tribes, nations, or places. This is in accord with modern Arabian custom. The Arabs make alliances with other tribes under the fiction of kinship, and then to justify the supposed kinship trace their descent from a common ancestor.[1] In combining the personifications of two documentary sources in Genesis 10 confusion has, in at least one case, resulted. To the J writer (v. 8) the Cush who begat Nimrod was the *Kash* of the Babylonian inscriptions, *i. e.*, the Kassites or Cossaeans, who, entering Babylonia from the East, conquered it about 1750 B.C. and established a dynasty that ruled for 576 years. To the P writer of v. 6 Cush was Nubia, as already pointed out. The combination of these narratives by a later editor has made the two Cushes appear to be the same, so that some interpreters, not recognizing the difference, feel compelled to claim that the Assyrians are descended from a Hamitic race.[2]

We are, then, on safe historical ground, if we assume that at least a part of the patriarchal narratives consists of tribal history narrated as the experiences of individual men. To assume that all patriarchal story is tribal history, would be to create for ourselves new difficulties. When once a man, or a supposed man, has caught the popular imagination, tradition frequently attaches to his name

[1] Cf. Sprenger, "Geographie Arabiens" and "Lectures and Essays of W. Robertson Smith," 461. The position set forth in the text is not new. Many scholars have taken it.

[2] See Kyle, "The Deciding Voice of the Monuments in Biblical Criticism," 106.

stories, which were originally told of others. This could, if it were necessary, be illustrated by many examples, but it is unnecessary to occupy space to prove that which is familiar to every investigator of history or legend.

In applying the principle of interpretation drawn from Genesis, ch. 10, it is convenient to begin with the narratives connected with the twelve sons of Jacob. These correspond to the twelve tribes of Israel, and are probably simply personifications of those tribes. These sons are divided by the narratives into four groups, which are said to be respectively the offspring of four mothers. It is natural to suppose that, if these narratives represent tribal history, that there was an alliance between the tribes which composed each group before the groups themselves were formed into a union. Two of the groups are said to be the offspring of full wives of Jacob. These probably joined in an alliance with each other earlier than the two groups which are said to be descended from Jacob's concubines. In Jacob's marriages, then, and the stories of the birth of his children we probably have an outline of the history of the formation of the confederacy of the twelve Israelitish tribes. The nucleus of this confederacy was the tribes which counted their descent from Leah, viz: Reuben, Simeon, Levi, Judah, Issachar, Zebulon. These were the original tribes of Israel. Later were born the sons of Rachel; *i. e.*, the Rachel tribes came into the confederacy after the other six existed as a definite group. The name Leah means wild-cow; the name Rachel, ewe.[3] It has accordingly been suggested that these were simply the animal symbols of the tribes, and that the Leah tribes were cow boys and the Rachel tribes sheep raisers. Others hold that they were not economic, but totemistic, symbols. Whichever alternative is adopted, the interpretation of Leah and Rachel which makes them the symbols of the intertribal alliances is most probable. The application of the name Joseph to two of these tribes, for reasons which will be mentioned later, was probably not made until after the settlement in Palestine. Again the tribe of Benjamin was not differentiated from the other Rachel tribes until after the settlement in Canaan. Benjamin originally

[3] Delitzsch, "Prolegomena," 80. W. R. Smith, "Kinship," 2d ed., 254.

meant "sons of the south" or "southerners," and was given them because they were the southernmost of the Rachel folk. This southern position they occupied in Palestine, but could hardly have held as a nomadic tribe. The tradition that Benjamin is the youngest of Jacob's sons is a recollection of the late development of the tribe.

Similarly, the name Joseph seems to have been attached to the tribes of Ephraim and Manesseh after the settlement in Canaan. The name itself has had an interesting history. A Babylonian business document of the time of the first dynasty of Babylon (2225–1926 B.C.) had for one of its witnesses *Yashub-ilu*,[4] or Joseph-el. Thothmes III, who conquered Palestine and Syria between 1478 and 1447 B.C., records as one of the places which he conquered in Palestine *Ya-sha-ṗ'-ra*,[5] which Eduard Meyer many years ago recognized as Joseph-el. This equivalence is doubted by W. Max Müller, but is, so far as I can see, possible. How did the name of a Babylonian man become attached to a Palestinian city? There was at the time of the first dynasty frequent intercourse between Mesopotamia and Palestine. Documentary evidence of this will be cited below in connection with Abraham. Is it too much to imagine that a Joseph-el migrated, and that his name became attached to a Palestinian city? Not only have we in our own country many places named for men, but modern Palestine affords an example of a village that lost during the nineteenth century its name, *Karyet el-'Ineb*, and substituted for it the name of a famous sheik, *Abu Ghosh*.[6] If in some such way Joseph-el made its way into Palestine and Rachel tribes afterward settled in the region, the shortened form of the name, Joseph, might naturally become the name of their supposed ancestor.

The principle of interpretation gained from Genesis 10 compels us to suppose that the name Joseph came in in some such way, for in the historical period no tribe of Joseph appears. If the investi-

[4] "Cuneiform Texts, etc., in the British Museum," II., 23, 15.

[5] Mittheilung der Vorderasiatische Gesellschaft, 1907, p. 23. Muller thinks it equivalent to *Yesheb-el*, "God dwells." The Babylonian might also be so interpreted. The phonetic equivalence between Babylonian and Hebrew points rather to *Joseph-el*, and the Babylonian form may account for the Egyptian spelling.

[6] See Baedeker's "Palästina," 1910, p. 16.

gator is forced to this conclusion, how are the vivid narratives of the personal fortunes of Joseph to be accounted for?

The archæological discoveries of recent years have made it probable that the Joseph tribes alone were concerned in the Egyptian residence and bondage.[7] The stele of Merneptah,[8] to whom all Biblical indications point as the Pharaoh of the Exodus, clearly shows that Israel, or the Leah tribes, were already in Palestine. The fact that the Ephraimite document, E, recalls as the Judæan document J does not, the revelation of the name Yahweh,[9] and that the ark of the covenant was afterward preserved in an Ephraimite shrine,[10] point in the same direction. If these tribes alone had the Egyptian experience and were at first the sole guardians of the Egyptian tradition, when once they had come to regard Joseph as their ancestor it would be natural for many stories to cluster about his name. In this connection it is an interesting fact that several of the stories told of Joseph are almost identical with other stories and facts which archaeological research have brought to light, but which in their original setting are connected with other names. The chief of these are the following:

1. The story of Joseph's temptation by Potiphar's wife is strikingly parallel to the tale of two brothers—a tale in which the younger brother is subjected by his sister-in-law to the same temptation as Joseph, and, when, like Joseph, he repulses her, she professes to have been outraged by him, and plunges him into misfortune.[11] This story comes to us in a papyrus dated in the reign of Seti II., 1209–1205 B.C., and is accordingly very old.

2. The career of Joseph as ruler of Egypt is paralleled by the career of Dûdu or David, an official bearing a Semitic name, who seems to have held a high position under Amenophis IV. of the eighteenth Egyptian dynasty, before 1350 B.C. In the El-Amarna correspondence two letters addressed to this Dûdu by Aziru, king of the Amorites, occur. They tell their own tale, and are as follows:

[7] See Paton's article, "Israel's Conquest of Canaan," *Journal of Biblical Literature*, XXXII, 1–54.

[8] See Breasted's "Ancient Records, Egypt," III., § 617.

[9] Ex. 3: 13, 14.

[10] I Sam. 3 and 4.

[11] See Petrie's "Egyptian Tales," second series, London, 1895, 36 ff.

I.[12]

[1]To Dûdu, my lord, my father, [2]speaks Aziru, thy son, thy servant: [3]at the feet of my father I fall. [4]Unto my father may there be health! [5]O Dûdu truly I have done [6]the wish of the king, my lord, [7]and whatever is the wish [8]of the king, my lord, let him send [9]and I will do it. [10]Further: see, thou art there, [11]my father, and whatever is the wish [12]of Dûdu, my father, send it [13]and I will do it. [14]Behold thou art my father [15]and my lord and I am thy son. The lands of the Amorites [16]are thy lands, and my house is thy house, [17]and whatever thy wish is, [18]send, and I [19]shall behold and verily will do it. [20]And see, thou in the presence of [21]the king, my lord sittest. [22]. . . enemies [23]words of slander [24]before my father, before [25]the king, my lord, have spoken, [26]but do thou not count them just! [27]And behold thou in the presence [28]of the king, my lord, as a dignitary(?) [29]sittest . . . [30]and the words of slander [31]against me do not count as true. [32]Also I am a servant of the king, my lord, [33]and from the words of the king, my lord, [34]and from the words of Dûdu, my father, [35]I shall not depart forever. [36]But when the king, my lord does not love me, [37]but hates me, [38]then I—what shall I say?

II.[13]

[1]To Dûdu, my lord, my father, [2]speaks Aziru, thy servant: [3]at the feet of my lord I fall. [4]Khatib has come [5]and has brought the words [6]of the king, my lord, important and good, [7]and I am very, very glad, [8]and my lands and my brethren, [9]the servants of the king, my lord, [10]and the servants of Dûdu, my lord, [11]are very, very glad [12]when there comes [13]the breath of the king, my lord, [14]unto me. From the words [15]of my lord, my god, my sun god, [16]and from the words of Dûdu, [17]my lord, I shall not depart. [18]My lord, truly Khatib [19]stands with me. [20]I and he will come. [21]My lord, the king of the Hittites [22]has come into Nukhashshi, [23]so that I cannot come. [24]Would that the king of the Hittites would depart! [25]then, truly, I would come, [26]I and Khatib. [27]May the king, my lord, my words [28]hear! My lord, I fear [29]on account of the face of the king, my lord, [30]and on account of the face of Dûdu. [31]And now by my gods [32]and my messengers verily I have sworn, [33]O Dûdu and nobles [34]of the king, my lord, that truly I will come. [35]And so, Dûdu [36]and the king, my lord, and the nobles, [37]"truly we will not concieve anything [38]against Aziru that is unfavorable"—[39]even thus may ye swear by [40]my gods and the god A'. [41]And truly I [42]and Khatib are faithful servants of the king. [43]O Dûdu, thou shalt truly know [44]that I will come to thee.

In these letters Aziru constantly classes Dûdu with the king. He fears to offend Dûdu as he fears to offend the king. The words of Dûdu he counts as of equal importance to those of the king. Dûdu

[12] Winckler & Abel, "Thoutafelnfund von El-Amarna," No. 40 and Knudtzon's "Die El-Amarna Tafeln," No. 158.

[13] Winckler & Abel, No. 38 and Knudtzon, No. 164.

clearly occupied a position of power with the king similar to that ascribed to Joseph in Genesis.

3. The action of Joseph in storing up corn and then distributing it during a time of famine is paralleled by the course of Baba of El-Kab, who flourished under the eighteenth dynasty of Egypt about 1500 B.C., and who says in an inscription carved in his tomb, at the close of a description of the activities of his life:

> "I collected corn as a friend of the harvest-god. I was watchful in time of sowing. And when a famine arose, lasting many years, I distributed corn to the city each year of the famine."[14]

The principal features of Joseph's life are thus paralleled in ancient history. The careers of Baba and Dûdu are thoroughly historical; our knowledge of them rests upon contemporary documents. While the latter part of the tale of the two brothers contains much that is mythical, the portion which deals with the brother's wife is so natural, and presents such a vivid picture of Egyptian rural life, that there can be little doubt that it is based on a real incident.

When once a name has become prominent in a nation it tends, by a law of human nature, to gather to itself all the appropriate stories known. One heard at Harvard a generation ago stories told of the late Professor Andrew P. Peabody, which a generation before had been told in Germany of the absent-minded Professor Neander. Before our eyes to-day stories are attaching themselves to Colonel Roosevelt which originally were told of others. It is not too much to suppose that the stories known to us from the sources quoted attached themselves to the name of Joseph, and thus filled out to the later Israelites the figure of their shadowy patriarch. This supposition, confirmed by historical and legendary analogies, enables us to find in the Joseph stories real history. It is not, it must be confessed, the history of a real Hebrew patriarch, but it is real history of Egypt and Palestine and of real men in them. The history is recovered, too, by following historical methods and following historical analogies, and relieves us from the necessity of supposing with Winckler that Joseph is but a series of Tammuz myths, or with Jensen, that he is a group of Gilgamesh myths.

[14] Cf. Brugsch, "Egypt under the Pharaohs," London, 1881, I., 303 ff.

Our pursuit of the origin of the Joseph-stories has taken us far afield from the discussion of the tribal history of the patriarchs. The accounts of the marriages of the sons of Judah and of an episode in the life of Judah himself in Genesis 38 may easily be understood to be alliances made by that tribe with clans previously living in their territory. Judah in all the subsequent history stood apart from the other Hebrew tribes. That she formed in David's early reign and after the time of Solomon a separate kingdom was in part due to the larger element of Canaanite blood in her.

Similarly the story in Genesis 34 of Simeon and Levi[15] represents an unsuccessful and treacherous attack of those tribes on the ancient city. In this attack they were practically annihilated and their kinsmen regarded their punishment as just.[16] On the view that the patriarchal stories are adumbrations of tribal history, the traditions which ascribe the birth of the patriarchs Gad, Asher, Dan and Naphtali to slave mothers may indicate that these tribes joined the Israelitish confederacy later than the union between the two great groups of Leah and Rachel tribes. If this were the case, these tribes probably came into the confederacy after the settlement in Palestine, and were, presumably, Amorite or Canaanite tribes who were there already. In the case of the tribe of Asher this supposition receives some confirmation from documents outside the Old Testament.

The father of Aziru, the Amorite, who wrote the letters to Dûdu quoted above, was named Ebed-Ashera, Ashera being a goddess. Ebed-Ashera in his time was in frequent war with Gebal, whose king, Rib-Adda, complained to the king of Egypt in many letters preserved for us in the El-Amarna correspondence. Rib-Adda sometimes calls the people over whom Ebed-Ashera ruled Amorites (Amurru), sometimes the "men of Ebed-Ashera" and often the

[15] The story appears in two forms; one is by J and the other by a priestly writer. In the former Shechem appears on one side and Simeon and Levi on the other; Shechem violates Dinah and the brothers take terrible vengeance upon him. In the latter Hamor, the father of Shechem proposes honorable marriage for his son with Dinah, and all the sons of Jacob are represented as acting as one man. Cf. Carpenter and Harford-Battersby, "Hexateuch," 52 ff.

[16] Gen. 49: 5–7.

"sons of Ebed-Ashera." It would be easy in course of time for the Ebed to drop out and the tribe to be called "sons of Ashera" or "sons of Asher."[17] As this tribe in the period covered by the El-Amarna correspondence (1400–1350 B.C.) was in the same region in which the Hebrew tribe of Asher was afterward settled, it seems probable that the Hebrew tribe was the same as the earlier Amorite tribe. This would fit in well with the conclusion to which the tribal interpretation of Jacob's marriage points.

When the investigation moves back a generation in the patriarchal genealogies, the same principle holds, but new perplexities appear. It is clear that Esau is the personification of the Edomite nation, and Israel that of the nucleus of the Hebrews. Already in the time of Merneptah there was an Israel, which was a nation. Probably it consisted of the Leah tribes. But the Hebrew patriarch is also called Jacob, and most of the stories concerning him are told of him as Jacob. There is reason to believe that the name Jacob had an origin similar to the name Joseph.

In the reign of the Babylonian king, Apil-Sin (2161–2144 B.C.), two witnesses to a contract, Shubna-ilu and Yadakh-ilu gave the name of their father as *Yakub-ilu* or Jacob-el.[18] Another witness, Lamaz, had a Jacob-el as his father.[19] In the reign of the next king, Sin-muballit (2143–2124 B.C.), a witness named Nur-Shamash was the son of *Yakub-ilu,* or Jacob-el,[20] while another witness, Sin-erbiam, gave his father's name simply *Yakub,* or Jacob.[21] Seven hundred years later Thothmes III. records among the names of cities which he conquered in Palestine a city *Ya'ḳe-b'-ra,*[22] the Egyptian equivalent of Jacob-el. The probability is that some Babylonian who bore the name migrated to the west, and in course of time

[17] See, *e. g.,* Schrader's "Keilinschriftliche Bibliothek," Nos. 53, 54, 55, 56, 57, 59, 60, 62, 63, 64, 68, 69, 70, 71, 73, 75, 76, 77, 78, 83, 84, 86, 88, 91, 92, 101.

[18] "Cuneiform Texts, etc., in the British Museum," IV., 33, 22b.

[19] Meissner, "Altbabylonische Privatrecht," 36, 25.

[20] "Cuneiform Texts," VIII, 25, 22.

[21] "Cuneiform Texts," II., 8, 26.

[22] *Mitteilungen der vorderasiatische Gesellschaft,* 1907, p. 27.

The city seems to have been east of the Jordan and was, perhaps, the same as Penuel, Gen. 32: 31.

a city was named after him. Later, when the Hebrews settled near this city, they took over the name of its hero in shortened form as a name for their eponymous ancestor. All the reasons quoted above for the name Joseph apply here. Apart from stories of marriages and friction with Esau, which denote tribal relations, the one important tale connected with Jacob is his dream at Bethel. This was one of the stories by which the Hebrews justified to themselves their adoption of an old Canaanitish shrine. The stories of Isaac seem, in like manner, to be tales of alliance with Aramaeans, and tales of shrines like that at Beersheba. We have no extra Biblical material with which to compare them.

When the investigator takes up the stories of Abraham, moving back still a generation from the nation Israel, he is confronted with much material and with a wealth of conflicting theories. Of course to Jensen Abraham is a form of the Gilgamesh myth.[23] To Winckler and Zimmern Abraham is a moon god. The reasons for this latter view have seemed convincing to many. Abram, of which Abraham was but a variant form, has been held to be of West Semitic origin and to mean "exalted father."[24] It is really, as we shall see, of Babylonian origin and has another meaning. Tradition connects him with Harran and Ur, both seats of the worship of the moon god. In Babylonian hymns Sin, the moon god, is frequently called *Ab* or father.[25] Sarah or Sarai, the name of Abraham's wife, is the Hebrew equivalent of *šarratu*, "queen," an epithet of the consort of the moon god at Harran. Milcah, Abraham's sister-in-law (Gen. 11 : 29), is *Malkatu*, the name of a consort of the sun god and perhaps also of the moon god.[26] These are some of the arguments which seem to the adherents of this view conclusive. It must be confessed that many of the stories told of Abraham in Genesis are connected with shrines, and would be explicable on this view. Their purpose was undoubtedly to justify the use by Hebrews of the shrines of Shechem, Bethel, Hebron, and Beersheba. This is not, however, the whole of the matter. We have now evidence that

[23] "Gilgameshepos und der Weltliteratur," I., 256 ff.
[24] Briggs, Brown and Driver, "Hebrew Lexicon," 4.
[25] Cf. *Journal of Biblical Literature*, XXVIII., p. 166, n. 26.
[26] Schrader, "Keilinschriften und das Alte Testament," 3d ed., 364 ff.

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Abraham was in Babylonia a personal name. This evidence comes from Dilbad, a little place about eight miles south of Borsippa, and consists of some contracts in which an Abraham figures. Three of the documents are here translated:

I.[27]

[1]1 ox, broken to the yoke, [2]an ox of Ibni-Sin son of Sin-imgurani, [3]from Ibni-Sin [4]through the agency of Kishti-Nabium, [5]son of Eteru, [6]Abarama, son of Awel-Ishtar, [7]for 1 month has hired. [8]For 1 month [9]1 shekel of silver [10]he will pay. [11]Of it ½ shekel of silver [12]from the hand of [13]Abarama [14]Kishti-Nabium [15]has received.

The names of the witnesses then follow and the date, which is the 11th year of Ammizadugga, or 1967 B. C.

II.[28]

[1]To the patrician [2]speak [3]saying, Gimil-Marduk (wishes that) [4]Shamash and Marduk may give thee health! [5]Mayest thou have peace, mayest thou have health! [6]May the god who protects thee [7]keep thy head in good luck! (To inquire) [8]concerning thy health I am sending. [9]May thy welfare before Shamash and Marduk [10]be eternal! [11]Concerning the 400 *shars* of land, the field of Sin-idinam, [12]which to Abarama, [13]to lease, thou hast sent; [14]the land-steward and scribe [15]appeared and [16]on behalf of Sin-idinam [17]I took that up. [18]The 400 *shars* of land to Abarama [19]as thou hast directed [20]I have leased. [21]Concerning thy dispatches I shall not be negligent.

III.[29]

[1]1 shekel of silver, [2]the rent of his field [3]for the year that Ammizadugga, the king, (set up) [4]a lordly, splendid statue (*i. e.* Ammizadugga's 13th year), [5]brought [6]Abarama; [7]received (it) [8]Sin-idinam [9]and Iddatum. [10]Month Siman, (May–June) 28th day, [11]the year Ammizadugga, the king (set up) [12]a lordly, splendid statue.

These documents are conclusive proof that Abarama, or Abraham, was a personal name in Babylonia. The name apparently meant, "He (*i. e.*, some god) loves the father." The Abraham revealed in these documents was not the patriarch, but was a small farmer in Babylonia. His father was Awel-Ishtar, not Terah; his brother, Iddatum, not Nahor. His existence, however, shows that, just as

[27] *Vorderasiatische Schriftdenkmäler der königliche Museen zu Berlin*, VII., No. 92.

[28] *Ibid.*, No. 198.

[29] *Ibid.*, No. 97.

in the cases of Jacob and Joseph, a living person probably existed far back in history about whose name stories, gathered from various quarters, afterward clustered.

That such a person may have migrated from Babylonia to Palestine, as the Biblical patriarch is said to have done, is clearly attested by an interesting little contract from Sippar, which reads as follows:[30]

[1]A wagon [2]from Mannum-balum-Shamash, [3]son of Shelibia, [4]Khabilkinum, [5]son of Appanibi [6]on a lease [7]for 1 year [8]has hired. [9]As a yearly rental [10]2/3 of a shekel of silver [11]he shall pay. [12]As the first of the rent [13]1/6 of a shekel of silver [14]he has received. [15]Unto the land of Kittim [16]he shall not drive it. (After the names of the witnesses comes the date.) [22]Month Ulul, day 25th, [23]the year the king as a friend protected Erech from the flood of the river.

The date of this interesting document has not been identified with certainty, but it probably comes from the reign of Shamsuiluna (2080–2043 B.C.). The country Kittim mentioned in it is the Mediterranean coast, which was sometimes so called by the Hebrews (cf. Isa. 2: 10, and Eze. 27: 6). The interesting thing is that intercourse between the Babylonian city of Sippar and the Mediterranean coast was so frequent when this contract was made, that a man could not lease his wagon for a year without running the risk that it might be driven to the Mediterranean coast lands. It was in a period of such frequent intercourse that some Joseph-el and Jacob-el migrated from Babylonia and gave their names to Palestinian cities. And it would seem that some Babylonian Abraham may have done the same, for Sheshonk I., of the twenty-second Egyptian dynasty (the Shishak of the Bible), records as one of the places captured by him in Palestine a place called "The field of Abram."[31] This place would seem to have been in southern Judah. It would seem quite as likely that a Babylonian Abraham may have given his name to the place in the same way that a Jacob-el and a Joseph-el did, and that, after Hebrews had settled in the country, they took his name over, just as they did the other two, as to suppose that the name Abraham originated in an epithet of a moon god.

One cannot well refuse to believe that many of the stories con-

[30] See *Beitrage zur Assyriologie*, V., p. 488, No. 23; cf. p. 429 ff.
[31] See Breasted, "Ancient Records, Egypt," IV., 352, 353.

nected with Abraham grew up in Palestine around certain shrines. They were the instruments by which Israel justified her use of these shrines. Other stories, like that in Genesis 18, 19, arose as the explanation of natural phenomena, such as the existence of the impressive gorge of the Dead Sea, and probably in their earliest form had no connection with Abraham. One can hardly believe, in view of all the evidence presented, that Abraham was the real ancestor of all the peoples said to be descended from him, any more than he can believe that all Egyptians were descended from one, Mizraim, but it is no longer unthinkable that the stories collected about Abraham have been attached to the name of a real man, who once migrated from Babylonia.

This paper cannot conclude without some remarks about the historical character of the fourteenth chapter of Genesis. Critics agree that it does not belong to either of the four great documents of the Hexateuch, and a considerable unanimity of critical opinion has been reached in recent decades, that it is later than all of them, and that it is a kind of Jewish midrash of a thoroughly unhistorical character. On the other hand, a large group of conservative scholars have endeavored to show from Babylonian texts that it is real history—history the authenticity of which is confirmed by the monuments. What are the facts as they appear to an unprejudiced mind? They are as follows:

Hammurapi, the great Babylonian lawgiver, one of the most important of all the Babylonian kings, reigned from 2123 to 2081 B.C., and claimed sovereignty of *Mar-tu,* or the Westland, probably Syria and Palestine. Many scholars have held that Hammurapi was the same as Amraphel of Gen. 14: 1. The names would exactly correspond were it not for the *l* at the end of Amraphel. By no known philological equivalence does that letter belong there, and if Hammurapi is intended by Amraphel, Gen. 14 must have been written so late that the name had become corrupted in a way similar to the corruption from which good Hebrew names have suffered in the angelic lists of the Ethiopic Enoch.[32]

[32] See the writer's article, "Origin of the names of Angels and Demons in the Extra-Canonical Apocalyptic Literature to 100 A. D." in *Journal of Biblical Literature,* XXXI., 156 ff.

Arioch, king of Elassar (Gen. 14: 1), has been identified with Rim-Sin, king of Larsa, a contemporary of the latter part of the reign of Hammurapi. But the fact is the name of Rim-Sin could not even in Sumerian possibly be read Ari-aku. That of his brother, Arad-Sin, might be so read, but there is nothing to lead us to suppose that it was, and there is no evidence that either Arad-Sin or Rim-Sin were ever in friendly alliance with Hammurapi.[33]

Again, much has been made of the fact that Kudur-Mabug, the father of Arad-Sin and Rim-Sin, who was the "Ad-da" or ruler of Emutbal, a district of western Elam, calls himself "Ad-da" of *Mar-tu*,[34] which has been supposed to be Palestine. *Mar-tu*, however, simply meant the place of sunset, and probably in this inscription refers to the western part of Elam.[35] There is really nothing whatever to connect Kudur-Mabug with Palestine at all. And even if there were, his name is not Cherdorlaomar, so that again the inscription would be evidence of the lack of information on the part of the Biblical writer.

Much has been made by Professors Sayce[36] and Hommel of four documents published by Pinches in the *Transactions of the Victoria Institute*, XXIX., 82 ff., which, according to Sayce and Pinches, contain the names of Arioch, Cherdorlaomar, and Tidal, the three kings, who in Gen. 14: 1 are associated with Amraphel. The documents are written in Semitic and are from the Persian period, not earlier than the fourth century B.C.

In reality neither the names Cherdorlaomar nor Arioch appear in the text. The name read Kudurlakhmal is really *Ku-ku-ku-mal* or *Ku-dur-ku-mal*. The other reading is only obtained by giving to the sign *ku* a value, *lakh*, altogether unattested by the cuneiform literature. The name read Eri-eaku and identified with Arioch is spelled in two ways. If read as Sumerian, it might be Eri-eaku. The text in which it occurs is, however, Semitic, and it is probable that the name is to be read here in Semitic fashion. So read it

[33] Cf. *Journal of Biblical Literature*, XXVIII., 158 ff.

[34] "Cuneiform Texts," XXI., 33.

[35] See Price, Decennial Publications of the University of Chicago, V., 167 ff.

[36] Cf. PSBA. XXVIII., 203–218, 241–251; XXIX., 7–17. Cf. also King, "Letters and Inscriptions of Hammurabi," I., p. li ff.

becomes Arad-malkua, or Arad-malaku. Tudkhula, the supposed Tidal, is not called in the document a king at all. To identify him with "Tidal, king of the nations," is a purely fanciful procedure.

It should be noted that in the documents which record these names Arad-malaku, the supposed Eri-aku, takes no part in the wars described; it is his son, Dursil-ilâni (who, by the way, has a good Semitic name) who is represented as the contemporary of Kukukumal, the supposed Cherdorlaomar. It should be further noted, that these documents represent a complete conquest of Babylon by Elam—a conquest so complete that:

"In their faithful counsel unto Kukukumal, king of Elam,
They [the gods] established the fixed advance, which to them seemed good.
"In Babylon, the city of the gods, Marduk set his [Kukukumal's] throne,
All, even the Sodomites of the plundered temples, obey him.
Ravens build their nests; birds dwell [therein];
The ravens croak(?), shrieking they hatch their young [in it].
To the dog crunching the bone the Lady . . . is favorable.
The snake hisses, the evil one spits poison."

This quotation from the second of the documents published by Pinches describes a complete subjugation and desolation of Babylon by Kukukumal, king of Elam. This definitely excludes the possibility that Kukukumal could have acted in harmony with Hammurapi, as Cherdorlaomar is said to have done. Indeed, it shows that he was not a contemporary of Hammurapi at all, for during his powerful reign there was no such conquest of Babylon by Elam. There were many conquests of Babylonia by the Elamites, and this must refer to some other period. In the documents themselves there is evidence that another period is intended, for Babylon is called by its Cassite name, Kar-duniash, a name that it did not bear until three or four hundred years after Hammurapi.

If the fourteenth chapter of Genesis was influenced at all by these documents, it is only another proof that the critics have been right, and that the chapter is not an authority as history.

Bryn Mawr College,
April 17, 1913.

THE DETERMINATION OF URANIUM AND VANADIUM IN THE CARNOTITE ORES OF COLORADO AND UTAH.

By ANDREW A. BLAIR.

(*Read April 17, 1913.*)

The determination of uranium in ores has become a matter of importance, due to the discovery of ores containing this element in Colorado and Utah and the constantly increasing demand for them. In these ores the uranium is associated with two to four times as much vanadium and varying amounts of silica, alumina, oxide of iron, lime and magnesia. They are practically free from phosphoric acid and sulphides, and contain very small amounts of metals precipitated by hydrogen sulphide in an acid solution. The problem thus is practically the separation of the uranium and vanadium from the alumina and oxide of iron, and their separation from each other. The first part of the problem is readily solved by the use of ammonium carbonate, which dissolves the uranium and vanadium and precipitates the oxide of iron and alumina. The separation of uranium from vanadium is more difficult, owing to the strong affinity between these elements. The volumetric method seems to offer an ideal separation as hydrochloric acid reduces the vanadium to the vanadyl condition without affecting the state of oxidation of the uranium and subsequent evaporation with sulphuric acid and titration with permanganate gives an accurate method for the determination of the vanadium. Subsequent reduction by aluminum reduces the uranium to UO_2, but it also reduces the vanadium theoretically to the state of V_2O_2, but upon the removal of the aluminum the vanadium absorbs oxygen so quickly that the actual state of oxidation is uncertain and the titration becomes unreliable. In Low's "Technical Methods of Ore Analysis," page 204, the method relies on the precipitation of the vanadium as lead vanadate in the presence of free acetic acid for its separation from the uranium, and while with great care this may be accomplished with more or less

accuracy it leaves much to be desired in the way of simplicity and ease of manipulation.

The method given by Carnot[1] for the determination of vanadium by adding uranyl nitrate and precipitating the ammonium uranyl vanadate in a solution slightly acid with acetic acid lends itself admirably to the reverse determination, and in the presence of an excess of vanadic acid the uranium may be accurately and easily determined.

Ammonium uranyl vanadate is a canary yellow flocculent precipitate resembling sulphide of arsenic. It settles rapidly and is quite insoluble in a solution faintly acid with acetic acid. It must be washed with a hot solution containing about 5 c.c. of slightly acid ammonium acetate to 100 c.c. of water, as it is slightly decomposed by pure water, passes through the filter and is reprecipitated in the filtrate. Upon ignition the V_2O_5, $2UO_3(NH_4)_2O + H_2O$ loses ammonia and water and becomes V_2O_5, $2UO_3$. It burns readily, but should not be heated above a low red, as it fuses and becomes very insoluble. Even when not fused it dissolves with difficulty in a large excess of dilute nitric acid. Fusing the salt does not appear to change its composition or the degree of oxidation of the uranium as the weight remains constant. When fused, a little hydrofluoric acid added to the dilute nitric acid causes it to dissolve more readily.

Determination of Uranium.

Boil two grammes of the finely ground ore with 25 c.c. of strong nitric acid and 25 c.c. water for half an hour, dilute and filter. Reject the insoluble portion. Neutralize the filtrate with ammonia and after a precipitate has formed add a strong solution of ammonium carbonate in excess. A large excess of ammonium carbonate is to be avoided as it dissolves appreciable amounts of both alumina and oxide of iron. This precipitates the alumina, oxide of iron, etc., while the uranium and vanadium are dissolved. The volume of the solution should be about 250 c.c. The solution should be warm but not hot, 40°–50° C. is a good temperature. Stir constantly for fifteen or twenty minutes and allow the precipitate to settle. Decant as much as possible of the clear liquid on the filter, and finally pour

[1] "Traité d'Analyse des Substances Minerales," Vol. II, p. 791.

on the precipitate and wash it two or three times with water containing two grammes of ammonium carbonate to the 100 c.c. Evaporate the filtrate. Dissolve the precipitate in a small quantity of hot dilute nitric acid and reprecipitate as before. Filter and add the filtrate to the first one. Evaporate until the ammonium carbonate is expelled and acidulate with a few drops of nitric acid. Evaporate until the volume of the solution is about 200 c.c., transfer to a 400-c.c. beaker, and add ammonia until a precipitate appears. Add nitric acid drop by drop until the solution clears, then add 10 to 15 c.c. of ammonium acetate, made by adding 30 per cent. acetic acid to strong ammonia until the liquid is acid to litmus paper. This will require a little over three volumes of acetic acid to one volume of ammonia. The precipitate which forms immediately is the ammonium uranyl vanadate V_2O_5, $2UO_3$, $(NH_4)_2O + H_2O$, mentioned by Carnot. After boiling for a few minutes it settles rapidly, leaving a clear supernatant liquid. Decant the clear liquid on a filter and wash twice by decantation with hot water containing 5 c.c. of the ammonium acetate mentioned above to 100 c.c. of water. Wash the precipitate onto the filter and wash several times with the same solution. Dissolve the precipitate adhering to the beaker in hot dilute nitric acid, pour it on the filter allowing the solution to run into a small beaker. Wash the filter with dilute nitric acid and hot water and evaporate the solution to dryness, without heating above water bath temperature. Dissolve in a little hot dilute nitric acid and add ammonia until a precipitate forms, then ammonium carbonate to dissolve the uranium and vanadium and precipitate any alumina and silica. Allow to stand until the precipitate settles, filter, wash with ammonium carbonate, acidulate the filtrate with nitric acid, boil off the carbonic acid and precipitate by ammonia and ammonium acetate as above. Filter, wash, ignite at a low red heat and weigh as V_2O_5, $2UO_3$, which contains 74.48 per cent of U_3O_8.

The success of this method depends on the presence of more than a sufficient amount of vanadic acid to form a precipitate of the composition mentioned, and this is the case with all the ores I have seen from these localities. It is well, however, to make sure of this and therefore the filtrate from the first precipitation of ammonium uranyl vanadate should be acidulated with nitric acid and a few

drops of hydrogen peroxide added. If the liquid becomes brownish yellow in color it shows an excess of vanadic acid. If it does not it is better to take a fresh portion and add a solution of vanadic acid in nitric acid. The amount to be added can be judged by the appearance of the precipitate of ammonium uranyl vanadate formed in the first instance.

Second Method for the Determination of Uranium.

In the presence of large amounts of alumina and oxide of iron an extremely accurate separation of uranium may be made by using the reaction suggested by Gooch & Havens,[2] by which aluminum chloride is precipitated in a crystalline form free from iron in a solution of equal parts of ether and the strongest hydrochloric acid saturated with hydrochloric acid gas. Havens[3] has shown that this method gives a separation of alumina from beryllium, zinc, copper, mercury and bismuth. I have found that it gives an excellent separation from uranium and vanadium and the method as worked out is as follows:

Treat two grammes of ore as directed in the method described above for the determination of vanadium and after evaporating the hydrochloric acid solution to syrupy consistency, transfer it to a narrow graduated beaker of about 100 c.c. capacity, using concentrated hydrochloric acid to wash all the solution from the larger beaker. The liquid should not exceed 20 c.c. to 25 c.c. in volume. Cool the liquid to about 15° C., and saturate it at that temperature with hydrochloric acid gas. The gas may be generated from rock salt or ammonium chloride in lumps and strong sulphuric acid and the current of gas should be constant and of considerable volume.

When the gas is no longer absorbed but passes freely through the liquid in the beaker note the volume and add an equal volume of ether. Saturation of the liquid generally increases the volume about one fifth and to obtain a satisfactory separation of alumina the volume of ether added should equal the volume of the saturated solution. Continue passing the gas until the solution is again saturated, being careful to keep the temperature of the solution close

[2] Gooch, "Methods of Chemical Analysis," p. 204.
[3] *Loc. cit.*, pp. 216, 217.

to 15° C. Hydrous aluminum chloride is precipitated together with lead chloride, while iron, uranium, vanadium, etc., remain in solution. Prepare an equal volume of hydrochloric acid and ether saturated as described above at 15° C. to wash the precipitate of aluminum chloride.

Filter on a Gooch crucible, allowing the solution to run into a beaker in a bell-jar and wash with the prepared solution. Heat the filtrate and washings carefully, evaporate to syrupy consistency and make an ether separation in the usual way. The ethereal solution contains the ferric chloride and any molybdenum that may be in the ore, while the acid solution contains the uranium, vanadium, lime, etc. Evaporate the solution nearly to dryness, replace the hydrochloric acid by nitric acid, and evaporate to dryness at water bath temperature. This oxidizes the vanadium and uranium to the vanadic and uranic conditions. Add a few drops of nitric acid and dilute the solution, add ammonia until a permanent precipitate forms, then excess of ammonium carbonate to dissolve the uranium and vanadium, and filter to get rid of any small amounts of alumina, and oxide of iron that may not have been removed by the operations described above. Determine the uranium as described in the first method as uranyl vanadate.

Determination of Vanadium.

Boil 2 grammes of the finely ground ore with 10 c.c. of nitric acid and 10 c.c. of water, add hydrochloric acid in excess, evaporate to dryness, redissolve in hydrochloric acid, dilute and filter. Reject the insoluble matter. Evaporate the filtrate to syrupy consistency and make an ether separation to get rid of the iron. Evaporate the hydrochloric acid solution very low, add 25 c.c. or 30 c.c. hydrochloric acid and repeat the evaporation several times to insure the reduction of the vanadium to vanadyl chloride. Add 5 c.c. strong sulphuric acid and evaporate until fumes of sulphuric acid are given off. Cool, dissolve in water, and titrate at a temperature of about 60°–70° C. with permanganate solution in a volume of about 100 c.c. The iron factor of the permanganate multiplied by 1.6342 gives the V_2O_5, taking vanadium as 51.0.

Philadelphia, April, 1913.

SUETONIUS AND HIS BIOGRAPHIES.

By JOHN C. ROLFE.

(*Read April 17, 1913.*)

Suetonius' "Lives of the Cæsars" is a work which is less well known to us than it ought to be. Its frequent citation in historical writings and in treatises on Roman antiquities might seem to make this statement a questionable one, but it is justified both by the rarity of the appearance of the author in our college courses of study, and by the publication of so few editions of the "Cæsars" or of individual lives in English; while no full and satisfactory commentary exists in any language, so far as I know.

The work has the unusual distinction of three *editiones principes*, of which two appeared in Rome in 1470 within a few months, and one in Venice the year following. Between that date and 1820 more than forty editions were issued, including some reprints, under the names of such scholars as Erasmus, Stephanus, Casaubon, Burmann and Ernesti. Bentley commenced an epoch-making edition which was never finished, and between 1606 and 1796 three translations into English were made.

Since 1820 the publications dealing with the "Cæsars" have been relatively few. In 1858 C. L. Roth issued a text which was the standard until 1906, when L. Preud'homme published a new recension, followed the next year by that of M. Ihm. No commentary on the entire work has been made since that of Baumgarten-Crusius in 1816, several times reprinted and with some additions by Hase (Paris, 1826). This is naturally not up to date, besides being far from complete. In English we have had editions of the "Julius and Augustus,"[1] the "Augustus,"[2] and "Tiberius-Nero,"[3] and com-

[1] H. T. Peck, New York, 1893[2].
[2] E. S. Shuckburgh, Cambridge (England), 1896.
[3] J. B. Pike, Boston, 1903.

mentaries on "Claudius"[4] and "Galba-Vitellius"[5] have been published abroad. Ihm seems to have had a full commentary in mind, but the appearance of this, as well as of his new text of the fragments, has been delayed, if not prevented, by his untimely death. A survey of the philological journals, both in English and in foreign languages, shows few articles dealing with Suetonius, compared with the number of those devoted to the text and elucidation of many other Roman writers.

The neglect of an author once so popular may be attributed in the main to two causes: first, to a more critical attitude towards the Roman writers as regards their style and a tendency to restrict the reading of the modern student to those which are rated as "classical" in the restricted sense of the term; and secondly, to a more rigorous standard in historical investigation, which has thrown discredit on Suetonius as a source.

While Suetonius must be condemned on both these counts, there are reasons which make the relegation of his biographies to comparative obscurity unfortunate. They are a mine of information on public and private antiquities, they are of surpassing interest for their wealth of anecdote and curious detail, and they are an important representative of a branch of ancient literature of which few examples have come down to us.

The vogue of Suetonius in still earlier days than those of the printed editions is shown by the great number of existing manuscripts, which are counted by hundreds. These are all apparently derived from a single survival, which formed a part of the library at Fulda in 844, as we know from a letter of Servatus Lupus,[6] abbot of Ferrières, at whose request a copy was sent to France and extensively copied. The original *codex Fuldensis* has since been lost.

As in the case of Horace, a multiplicity of manuscripts has rather added to the difficulties of editors than favored their attempts to establish a standard text. The greater number belong to the fourteenth and fifteen centuries, and are suspected of containing the cor-

[4] H. Smilda, Groningen, 1896.

[5] C. Hofstee, Groningen, 1898.

[6] L. Traube, *Neues Archiv der Gesellschaft für ältere Deutsche Geschichtskunde*, XXVII., pp. 266 ff.; cf. *Hermes*, XL., p. 179.

rections and interpolations of the scholars of that period. The emendation of a text disfigured by lacunæ and errors began in fact at an earlier period and had tended to disguise the readings of the archetype as early as the twelfth century.

We have a few manuscripts of admitted superiority, the *Memmianus* of the ninth century, the *Gudianus* of the twelfth, and *Vaticanus 1904*, of about the same date as the latter, but unfortunately coming to an end in the third chapter of the "Life of Caligula." Of these the first is comparatively free from emendations, but it has numerous errors and lacunæ, including the extensive gap at the beginning of the "Life of Julius." The missing portion of this "Life" was apparently still in existence in the sixth century, when Johannes Lydus used a codex[7] containing the missing dedication to C. Septicius Clarus, prefect of the prætorian guard, and hence presumably the opening chapters of the "Life of Julius." These must therefore have disappeared between the sixth and the ninth centuries. To the evidence for their existence, which has been questioned by some, we may add a statement of the commentator Servius[8]; "Suetonius ait in vita Cæsaris responsa esse data per totum orbem nasci invictum imperatorem." This remark, if we may trust Servius for its genuineness, must have been made in the missing portion of the "Life of Julius." Moreover, the general plan of the biographies obliges us to assume a lacuna, and the arguments against it are wholly unconvincing.

The rest of the manuscripts fall into two classes, each represented by numerous codices, of which the second contains more errors and emendations than the first. Individually the manuscripts are of comparatively little value, but their archetypes, whose readdings may be recovered from their agreement, are more important, especially that of the first class, which seems to be derived from the same original as the *Vaticanus*.

There is comparatively little difference of opinion as to the value and relationship of the earlier manuscripts. Ihm and Preud'homme, as the result of careful and independent investigations, arrived at

[7] "De Magistr.," 2, 6, p. 102 Fuss.
[8] On Verg. "Æn.," VI., 799.

substantially the same conclusions, and while they differ in their estimate of the relative importance of some few codices, their texts show very slight and unimportant variations one from the other. We might therefore regard the text of Suetonius' "Cæsars" as settled, barring the possibility of the discovery of new material, were it not for the difference of opinion as to the independent value of the later manuscripts.

These codices frequently offer readings superior to those of the earlier ones, but, as has been said, it is suspected that they are the corrections of scholars of the fourteenth and fifteenth centuries and hence of no weight in determining the readings of an archetype. This conclusion was reached by Roth in 1858, but it has since been called in question by various scholars.[9] At present, however, the weight of evidence is on Roth's side, since Ihm and Preud'homme have arrived at the some conclusion through more extensive and thorough studies[10] than have as yet been made public by the supporters of the contrary view. As a matter of fact, except for greater conservatism in the later editions, which is in accord with the current conception of textual criticism, and greater reserve in filling lacunæ, the texts of Ihm and Preud'homme show remarkably few deviations from that of Roth, so that any radical changes must be the result of the demonstration of the independent value of the later manuscripts or of the discovery of fresh material.

As to Suetonius himself our information is somewhat scanty, since he is one of many Roman writers who make few allusions to themselves; in fact the character of his work is not such as to call for revelations of that kind. What we do know is derived for the most part from the "Letters" of the younger Pliny, to whom we

[9] Chr. Modderman, "Lectiones Suetonianæ," Groningen, 1892; H. N. Veldhuis, "Annotationes Criticæ," Leyden, 1897; C. L. Smith, *Harvard Studies in Class. Phil.*, XII. (1901), pp. 54 ff.; A. A. Howard, *id.*, pp. 261 ff.; and others.

[10] Preud'homme, "Première, deuxième, troisième étude sur l'histoire du texte de Suétone de vita Cæsarum," in the *Bulletins de l'Académie royale de Belgique*, 1902, and *Mémoires couronés et autres mémoires publiés par l'Académie royale de Belgique*, LXIII., pp. 1–94; Ihm, *Hermes*, XXXVII., pp. 690 ff. and the introd. to his edition, Leipzig, 1907.

also owe information about his uncle, the elder Pliny,[11] Silius Italicus,[12] Martial,[13] and other writers of the day. C. Suetonius Tranquillus, as he himself tells us,[14] was the son of Suetonius Laetus, a Roman knight, who in April of the year 69, as tribune of the Thirteenth Legion, took part in the battle of Betriacum, where Otho's forces were defeated by those of his rival Vitellius. In other casual allusions of a personal nature, four in number,[15] Suetonius gives us no additional information of importance, although they are of some help in drawing conclusions as to the date of his birth.

His birthplace is unknown. Arguing *ex silentio,* it is possible to infer that he was one of the few Roman writers who were born in the city itself.[16] The dates of his birth and death are also uncertain. The former is assigned by Mommsen[17] to the year 77; by Macé with somewhat greater probability to 69.[18] To determine the exact year is impossible, but the facts of his life, so far as we know them, point to the beginning of the reign of Vespasian. The date of his death is equally uncertain. Our last reference to him as still living is in the year 121, but the implication in one of Pliny's letters[19] that he was slow to publish, taken in connection with the long list of his writings, would seem to indicate that he must have lived to a good old age, including a part of the reign of Antoninus Pius.

From another of Pliny's letters, a reply to a request to have a suit in which his friend is about to plead postponed in consequence of an unfavorable dream,[20] we learn that Suetonius practised at the

[11] III., 5; VI., 16 and 20.

[12] III., 7.

[13] III., 21.

[14] Otho, 10, 1.

[15] Calig., 19, 2; Domit., 12; Nero, 57, 2; cum post viginti annos (after Nero's death), adulescente me, extitisset condicionis incertae qui se Neronem esse iactaret; Gr. 4.

[16] The number of these is at most small, and there is no writer of prominence about whom it can be asserted positively; it is probable in the cases of Cæsar, Lucretius and Suetonius; cf. Macé, "Essai sur Suétone," Paris, 1900, pp. 33 ff.

[17] *Hermes,* III., p. 43.

[18] *L. c.,* pp. 35 ff.

[19] V., 10.

[20] I., 18.

bar, at least for a short time. From a third reference of Pliny[21] Macé and others have assumed that Suetonius was a teacher, and the former, with the imagination characteristic of French scholarship, constantly refers to him as a "maître d'écôle" and draws inferences from his profession. But the most natural interpretation of *dominis scholasticis* in the passage in question is "scholars turned land-holders," and there seems to be no evidence whatever that Suetonius was a schoolmaster.

Pliny's acquaintance with Suetonius was evidently an intimate one, since he twice refers to him as *contubernalis*.[22] This term, too, seems to imply that the two men were of approximately the same age and hence to support the view that Suetonius was born as early as the year 70. An equality in years is not inconsistent with the reverence[23] which he felt for his distinguished friend, whose position was so much higher than his own, and it is in accord with "Epist.," IX., 34, in which Pliny consults Suetonius as to the advisability of reading his verses in public.

Suetonius held no official position in his earlier years. Through Pliny's good offices he secured a military tribunate,[24] but soon had it transferred to a relative, Caesennius Silvanus. The same good friend secured for him the *ius trium liberorum* from Trajan,[25] although this privilege was not justified by the number of his offspring. That his marriage was unhappy, as well as unfruitful (*parum felix*), is a pure inference. Pliny himself was childless, though he too received the *ius trium liberorum* from Trajan[26]; but the happiness of his wedded life is apparent from several of his letters.[27]

The letters of Pliny which refer to Suetonius cover approximately the period from 96 to 112. When we next hear of him,[28]

[21] I., 24, 4.

[22] I., 24, 1; cf. X., 94, 1.

[23] III., 8, 1: reverentia quam mihi præstas.

[24] III., 8.

[25] X., 94, 95. The lex Papia Poppæa deprived childless men of one half of the legacies and inheritances left them, which made the *ius trium liberorum* particularly in demand.

[26] X., 2.

[27] IV., 19; VI., 4, 7; VII., 5; VIII., 10.

[28] Spartianus, "Vit. Hadr.," 11, 3.

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he is holding the responsible position of secretary under Hadrian (*Ab epistulis,* referred to by Spartianus by the later title of *epistularum Magister*). It is altogether probable that he owed this position to the influence of his friend and patron C. Septicius Clarus, to whom he dedicated the "Lives of the Cæsars," and that he held it while Septicius was prefect of the praetorian guard, from 119 to 121. Spartianus tells us in the same passage that both Suetonius and Septicius were dismissed by Hadrian, "quod apud Sabinam uxorem iniussu eius familiarius tunc se egerant quam reverentia domus aulicae postulabat." While this statement is far from definite, the words *iniussu eius* certainly imply some violation of court etiquette rather than any more serious misconduct. After this we lose sight of Suetonius, but it seems probable that he lived in retirement and devoted himself to study and publication.

Our references give us the impression of a man of quiet, scholarly tastes and habits, of no great ambition in other directions, who enjoyed the friendship of a number of distinguished men and from his connection with them and his position under Hadrian had the opportunity of gathering a great amount of information. This is confirmed by the allusions to his works, which are considerably more numerous, as well as by his reputation in later times. According to the fashion of his later years, when the greater part of his books were published, he seems to have written in Greek as well as Latin, although the fact that the titles of some of his works are known to us only in their Greek form is due to the sources in which they have been preserved. The lexicographer Suidas, of the tenth century, has given us a catalogue of his writings,[29] which has been supplemented from other sources,[30] while other references throw some light on the extent and interrelation of some of the books.[31] They are in the general fields of history (biography), antiquities, natural

[29] *S. v.* Τράγκυλλος

[30] Ps. Aur. Vict., "Epit.," 14; Servius on "Æn.," VII., 627; Lydus, "De Magistr.," 3, 64, p. 268 Fuss; Auson., "Ep.," 19, p. 180 Schenkl; Charisius, "Gr. Lat.," I., 236, 17 K.; etc.

[31] Isidore, "De Nat. Rerum," 38 and 44; Priscian, VIII., 20 and 21, XVIII., 149.

history and grammar, and comprise eighteen titles, which are variously arranged by different scholars.[32]

Of all these works only the "Lives of the Cæsars" has come down to us practically entire.[33] We have besides considerable portions of the "De Viris Illustribus," biographies of illustrious Romans in the fields of literature and philology, and numerous detached fragments from other books, preserved in the form of citations and excerpts by later writers.

While the historian of Latin literature can hardly class Suetonius higher than second rate, his influence was greater than that of many more eminent writers, partly because of his relatively high rank in the period of his activity, but especially because his "Lives of the Cæsars" appealed to the spirit of the age. Because of this they gave a biographical turn to historical writing which endured for centuries. They served as a model for Marius Maximus, who lived from about 165 to 230, and for the writers of the Augustan History ("Scriptores Historiæ Augustæ") of the time of Diocletian and Constantine, while Tacitus found a follower only in Ammianus Marcellinus (330–400). Their influence extended to the Christian writers, as appears from the biography of Ambrosius by his secretary Paulinus, and even to the Middle Ages, when Einhardus took the same pattern for his "Life of Charles the Great." Eutropius, Aurelius Victor and Orosius drew on him freely and often transcribe his language so faithfully as to be of some little value in questions of textual criticism; and he was used as a source by Greek writers such as Cassius Dio, Lydus, and others.

His other biographies were not neglected: Apuleius made use of his book "On Famous Courtesans," Hieronymus wrote of the "Illustrious Men" of the Church in imitation of Suetonius' work of the same title, while the ecclesiastical chronographers, such as Julius Africanus, drew on his treatise "On the Kings."

His antiquarian and grammatical works were equally influential. Tertullian based his "De Spectaculis" on a similar work of Sue-

[32] See Macé, *l. c.*, p. 355; Schanz, "Geschichte der römischen Litteratur," Part 3, pp. 53 f.; etc.

[33] See page 208, above.

tonius, while Censorinus, Solinus, Macrobius, the commentator Servius, the scholiasts on Horace, Germanicus and Juvenal, the grammatical writers, and especially Isidore, the learned bishop of Seville, excerpted him freely and extensively. In this field, too, his influence extended to the Greek and Byzantine writers and inspired and furnished material for numerous works on natural history in the Middle Ages.

From its title and its general form the "Lives of the Cæsars" is naturally classed as biography, and it is also numbered among our historical sources. Strictly speaking, however, it is neither history nor biography. Great historical events are dismissed in a brief chapter, like Cæsar's Gallic campaigns, or with a casual allusion, as in the case of the defeat of Varus. Constitutional history receives relatively greater attention, but this too is subordinated to the personality of the emperors, about whose qualities and characteristics the minutest and most intimate details are given. Chronology is neglected, except for the dates of birth and death.

But when we examine the "Lives" as biography, we find them lacking in some of its most essential features. As a matter of fact, biography as the "faithful portrait of a soul in its adventures through life"[34] has reached its full development in comparatively modern times, and even now there is not entire agreement as to its function. The writer in Larousse's "Dictionnaire Universelle," for example, says:[35] "la biographie ne s'occupe que de la vie humaine, et elle ne l'étudie que dans les actions exterieures des individuels." Yet I think that most of us would agree that a biography in the true sense of the word should be more than a mere catalogue and should show the development of character as the result of heredity, education and environment. Of this there is practically nothing in Suetonius. He rather furnishes us with the raw material for biographies and his "Lives" differ from the modern conception as widely as do annals from history.[36] It does not occur to him to make comparisons between the various individuals whom he portrays, or to draw the psychological deductions that cannot escape

[34] Encycl. Brit., *s. v.*, III., p. 952.
[35] *S. v.*, II., p. 257.
[36] See Sempronius Asellio in Gellius, V., 18, 5 ff.

the thoughtful reader. In the "Life of Caligula" he gives us an appreciative sketch of the noble father Germanicus, leaving the reader to note the contrast with his unworthy son. He does, it is true, express the opinion that the latter was sound neither in body nor mind, but he attributes to this, not his acts of madness and his change from benevolence to tyranny, but merely the existence in the same man of two opposite traits, contempt of the gods and extravagant fear of thunder and lightning.[37] He has noted this same fear in Augustus, who had good reason for it in a narrow escape from death, and in Tiberius; but he has no thought of regarding it as a family trait: still less as a form of degeneracy or the effect of a guilty conscience.[38]

It is unnecessary to multiply examples of this kind. His method is sufficiently illustrated by his own remarks.[39] It consists in general in giving an outline of the life of his subject, commonly preceded by a sketch of the history of his family, and followed by an enumeration of his deeds in war and in peace and an account of his private life and habits. His good and bad qualities are presented in separate lists, rarely with comment of any kind.[40]

The "Lives" differ no less from the original Greek conception of biography than from that of modern times. The former consisted in a description of the ideal βίος, the art of living, as a model for imitation,[41] and the type endured for many centuries. In this aspect biography approaches the domain of philosophy, and Wilamowitz finds its beginnings in Plato, although it did not become common until the Hellenistic period. Our greatest example is of course the "Parallel Lives" of Plutarch, who was a young man in the days of Nero and probably wrote his biographies under the Flavian emperors, although they were not published until a later time. Side by side with the philosophical biographies, however,

[37] Calig., 51, 1.

[38] Cf. Juvenal, XIII., 223 ff.

[39] Aug., 9, 61, 94; Tib., 61; Calig., 22; Nero, 19.

[40] See, however, Tib., 21; Vesp., 16, 3; Titus, 1; 10, 2, etc., and on the last-named cf. Leo, "Die griechisch-römische Biographie," pp. 9 ff.

[41] See Wilamowitz-Moellendorff in "Kultur der Gegenwart," I., 8, pp. 116 ff.

though of somewhat later origin, we have the so-called "grammatical" type of the Peripatetics, originally designed as introductions to works of literature and drawing their material in a great measure from those works themselves, but afterwards extended to men eminent in other fields.[42] These are of the same general character as those of Suetonius, and undoubtedly influenced the form of his "Lives of Illustrious Men" and of his "Cæsars."

In considering the indebtedness of works of Roman literature to Greek models we must make a distinction between form and contents. It is well known that the Romans had made beginnings in various lines of literary endeavor before their introduction to the masterpieces of the Greeks, which would have resulted in the development of a native literature quite different from that which we may properly call Græco-Roman. Although this development was checked, it is equally well known that from the outset the Roman writers showed originality in the use of their models, for example, in the "contamination" of Greek plays and in the early invention of the *fabula prætexta* and *fabula togata*. But the influence of the form of the Greek writings was powerful from the beginning, and as time went on, regular rules for the various classes of literary composition were formulated, from which a rhetorically trained writer seldom ventured to deviate. This, however, is not necessarily attended with a lack of originality in the subject matter and its treatment. Horace for instance in his "Odes" followed the general principles and metrical schemes of Alcæus and Sappho, as he freely admits,[43] but as Professor Gildersleeve has graphically expressed it:[44] "if Alkaios and the rest of the nine lyric poets were to rise from the dead, Horace would still be Horace." Similarly it does not detract in the least from the merits of the "Agricola" as a masterpiece of literature that its author followed the traditional rules for the compo-

[42] While it was maintained by Leo that these were composed on a generally uniform plan, the newly discovered "Life of Euripides" by Satyros shows a departure from the norm in being cast in the form of a dialogue, with one principal and two minor interlocutors.

[43] "Odes," III., 30, 10: Dicar . . . Princeps Aeolium carmen ad Italos Deduxisse modos.

[44] *Amer. Jour. of Phil.*, XXXIII., p. 360.

sition of encomiastic biography.[45] Therefore the fact that Suetonius took as his model the "grammatical" biographies of the Greeks does not mean that the Romans derived the idea of that branch of literature from across the seas. On the contrary, there are good reasons for supposing that biography was one of the numerous forms of writing in which a beginning had been made before the days of Livius Andronicus, and it seems altogether probable that considerable progress had been made before that time.

At first thought we should not be inclined to look to the Romans for a form of literature in which the personal element is so strong, at least in the earlier period of their history. It is a commonplace of criticism that at the beginning of their national life they were led by their situation to form a military and political organization in which the interests of the community were paramount and those of the individual distinctly subordinate. To this we may attribute the late and exotic impulse to many forms of creative literature and the prominence given to military science and to law. Heine's witty characterization of the people as "eine casuistische Soldateska" contains as much truth as any generalization epigrammatically expressed. The Greeks, on the contrary, exalted the individual, and their greatness in literature and the arts was in marked contrast to their failure to achieve political unity, and their consequent early relation to Rome of *Græcia capta*. That they were so late in developing a biographical literature is doubtless to be attributed to their original notion of the moral and didactic function of that class of writing and its subordination to other forms of philosophical teaching, and to the relatively restricted nature of the "grammatical" biography in its earlier stages.

In spite of the suppression of the individual in early Rome, there were certain customs which favored the production of biographies of a laudatory character, the purpose of which was in part moral precept, as with the Greeks, and in part the gratification of national and family pride. We are told that it was usual at banquets to sing the praises of illustrious men and their houses. Cicero twice alludes

[45] See Hendrickson, "The Proconsulate of Cn. Julius Agrippa," *Univ. of Chicago Decenn. Publ.*, VI., 29 ff.

to this custom,[46] each time giving Cato as his authority. Valerius tutem alacriorem redderent," while Varro,[48] referring to the same custom, says that the singers were *pueri modesti.* Horace also refers to such songs,[49] and Macaulay attempted to give an imitation of them in his "Lays of Ancient Rome." Granting him, as we may, a fair degree of success in reproducing their spirit, although their form was of course quite different, it is clear that such lays were not biography, although they contained material for such writings and two powerful impulses to their composition. The theory of Perizonius, which Macaulay followed, with regard to an early ballad literature is of course generally given up, but we have no ground for doubting the testimony of Cato and Varro as to the existence of the custom referred to.

The Romans possessed a closer model for biographical literature in the funeral eulogies which were spoken from the rostra by a son or some other near relative in honor of distinguished men and women, and in the eulogies of their ancestors by magistrates on their entrance to office.[50] The former custom must have been a very early one, for Livy tells us[51] that it was first extended to women after the capture of Rome by the Gauls, in gratitude for their contribution to the city's ransom, an indication of the antiquity of the custom, whatever be the truth of the statement itself. The epitaphs of the Scipios may be regarded as condensed summaries of such eulogies, stripped of their minor details. For example:

> Cornelius Lucius Scipio Barbatus,
> Gnaivod patre prognatus, fortis vir sapiensque,
> Quoius forma virtutei parisuma fuit,
> Consol, censor, aidilis, quei fuit apud vos.

[46] "Tusc. Disp.," IV., 2, 3: gravissimus auctor in Originibus dixit Cato morem apud maiores hunc epularum fuisse, ut deinceps qui accubarent canerent ad tibiam clarorum virorum laudes atque virtutes; "Brut.," 19, 75. Maximus[47] adds that their purpose was "quo ad ea imitanda iuven-

[47] II., 1, 10.

[48] In Nonius, s. v. *assa* (*vox*).

[49] "Odes," IV., 15, 25 ff.

[50] For the former see Polybius, VI., 53–54, and for the latter, Suet. Tib., 32, 1.

[51] V., 50, 7.

Taurasia, Cisauna, Samnio cepit;
Subigit omne Loucanam opsidesque abdoucit.[52]

In the eulogies themselves fuller details were given, as we see from Cæsar's funeral oration on his aunt Julia, a part of which is quoted by Suetonius.[53] In this oration Cæsar undoubtedly had a political purpose, as Napoleon had in his "Histoire de Jules César," and on other similar occasions, the opportunity was taken to justify one's own conduct or that of an ancestor.

That this custom led to the composition of formal biographies or at least to the publication of the funeral addresses themselves is a priori probable, and we have a parallel in the development of oratory as a branch of literature. According to Tacitus[54] the custom of publishing accounts of the lives of distinguished men (clarorum virorum facta moresque posteris tradere) was an ancient one (antiquitus usitatum), and we have references to such works, including autobiography,[55] at a comparatively early date. The custom naturally was given a fresh impulse by the growth of individualism at Rome, beginning with the domination of men like Sulla in times which might well be referred to by Tacitus as ancient, and reaching a high point with the foundation of the Roman empire.[56] To this period belongs one of our few surviving specimens of ancient biography, twenty "Lives" from the "De Viris Illustribus" of Cornelius Nepos, published about 44 B.C., which are of quite a different type than those of Suetonius.[57]

It is unnecessary to mention in detail, or to refer to all the biographies and autobiographies of which we have mention in this epoch and that of the early Empire.[58] While our only other surviving example is the "Agricola" of Tacitus, the interest of the Romans in this form of literature is sufficiently obvious.

[52] C. I. L., I., 30.
[53] Julius, 6, 1.
[54] Agricola, 1.
[55] See West, "Roman Autobiography," De Vinne Press, 1901.
[56] The same personal element appears in the historical writing of the period; cf. Leo, *l. c.*, p. 319.
[57] See Leo, *l. c.*, pp. 193 ff.
[58] For numerous references, and on autobiography as an original creation of the Romans, see West, *l. c.*

Although it may fairly be maintained that biography was original with the Romans, and although in the nature of the case the "Lives" of Suetonius are independent so far as their subject matter is concerned, the latter naturally followed the established rhetorical rules for the composition of such works. Just as Horace adopted the verse forms of Alcaeus and Sappho, so Suetonius took as his pattern the biographies of the Greek "grammatical" type,[59] since his purpose was not eulogy, but an impartial account, according to his own views of impartiality. Such merits, however, as his work possesses, and such defects as it labors under, are due to himself and not to any great extent to his models. That the books, interesting and valuable as they are, do not take first rank as literature is because he did not have the pen of a Tacitus; that they are rated no higher as an historical source is due to his lack of critical judgment.

The style of Suetonius is that of the investigator and scholar, rather than the man of letters. His purpose is clear statement, rather than rhetorical adornment or dramatic effect. He had no leaning towards the style which Seneca had made popular in his earlier years,[60] or that of the archaizers who set the fashion during his later life.[61] His ideas of an appropriate style appear in what he says of that of Augustus,[62] much of which might be applied to his own writings. As might be expected of a scholar, his choice of words is accurate and forceful, while his sentences are as a rule terse and packed with meaning. Now and then he turns out phrases worthy of Tacitus, but these seem to be due to his subject matter, like his intensely dramatic passages,[63] rather than to any conscious departure from his usual unadorned, "businesslike," and somewhat monotonous style.

Suetonius had at his command a wealth of sources of information, the greater number of which are lost to us, including historical works, memoirs, public records and documents, and private corre-

[59] Leo, *l. c.*

[60] Cf. Calig., 53, 2: Senecam tum maxime placentem; Nero, 52.

[61] See Seneca, "Epist.," 114, 13.

[62] Aug., 86.

[63] For example, the death of Julius Cæsar (82) and of Domitian (17), and the last hours of Nero (49).

spondence, published and unpublished. His intimacy with Pliny gave him access to senatorial opinion, while his position under Hadrian opened to him the imperial archives, either directly or through his colleague *Ab studiis*.[64] Few men could have had such opportunities, and he seems to have been as diligent a collector of material as the elder Pliny.[65] While he made little use of the inscriptions which are so highly valued in our day,[66] this was due to the abundance of his literary material and to the plan of his work. He occasionally makes use of them and shows an appreciation of their value.[67]

In general his methods are rather those of the scholar and investigator than of the inquirer and observer. He is a diligent searcher of records, but rarely records hearsay evidence, gathered from his grandfather and other men of the earlier time, or the results of his own observation.[68] As he comes nearer to his own day, when the former material was more scanty and the opportunities for gathering information of the latter kind more abundant, his interest visibly wanes. In the rare cases when he gives us an insight into his method of handling his material, as in the discussion of the varying opinions about the birthplace of Caligula,[69] he seems to examine it with care and good judgment, whenever he considered it necessary to do so; but the plan of his work seldom called for such critical methods, and it is quite possible that he has given us notice of all the cases in which he employed them. What he mainly desired was entertaining anecdotes and personalities, and he drew them indiscriminately from every quarter, either not realizing, or trusting his reader to discern that impartial opinions about Augustus were not to be expected in the letters and speeches of Mark Antony, or that one historian was not as trustworthy as another.

The result is that none of the Cæsars cuts a very heroic figure

[64] See Macé, *l. c.*, p. 110 f.

[65] Pliny, "Epist.," III., 5, 17.

[66] See Dennison, "The Epigraphic Sources of Suetonius," *Amer. Jour. of Arch.*, sec. ser., II., pp. 20 ff.

[67] See Aug., 7; Tib., 5; Calig., 23; Claud., 41; and for a full discussion of the subject, Dennison, *l. c.*

[68] See the references in note 15.

[69] Calig., 8.

in his pages. The great Julius appears as an unscrupulous politician, who aimed at supreme power from his earliest years and regarded any means of attaining it as justifiable.[70] He was ready to join in any attempt at revolution which seemed to promise success.[71] In spite of his moderate use of his victory and his many plans for the welfare of the state, Suetonius apparently believes that he deserved the fate which overtook him.[72] For Augustus and Titus he has an evident admiration, yet his method does not allow him to pass over the former's cold-blooded cruelty[73] and calculating seduction,[74] and the latter's violence, debauchery and shameless avarice.[75] In fact, his conscientiousness leads him even to record charges which he himself rejects.[76] On the other hand, he scrupulously recounts the good deeds and qualities of Tiberius, Caligula, Nero, and Domitian, although it is evident enough that his general opinion of those emperors is far from favorable. Vespasian fares best, for he is charged only with penuriousness, and even this Suetonius is inclined to justify on the ground of necessity.[77] Perhaps the most dramatic career of the whole series is that of the hard-headed, humorous Sabine, roused to seek political preferment only by his mother's taunts,[78] and retaining his simple habits and good common sense even after becoming ruler of the state. He bitterly offended Nero by going to sleep or leaving the theater while the emperor was singing,[79] was pelted with turnips at Hadrumetum,[80] and daubed with mud by order of Caligula for neglecting his duty of keeping the streets clean,[81] a fitting punish-

[70] Julius, 30, 5.

[71] Julius, 3, 5, 8, 9, 11.

[72] Julius, 76, 1: prægravant tamen cetera facta dictaque eius, ut et abusus dominatione et iure cæsus existimetur.

[73] Aug., 13, 27.

[74] Aug., 69, 1.

[75] Titus 7: constabat in cognitionibus patris nundinari præmiarique solitum.

[76] Claudius, 1, 5.

[77] Vesp., 16, 3.

[78] Vesp., 2, 2.

[79] Vesp., 4, 4.

[80] Vesp., 4, 3; Suetonius's naive sentence is worthy of a full quotation: exim sortitus Africam integerrime nec sine magna dignatione administravit, nisi quod Hadrumeti seditione quadam rapa in eum iacta sunt.

[81] Vesp., 5, 3.

ment for the offense and one of the flashes of genius of the madman who called Livia a "Ulysses in petticoats"[82] and dubbed Seneca's style "sand without lime."[83] While Vespasian lurked in retirement, fearful of Nero's vengeance for a lack of appreciation of his histrionic talents, opportunity found him in the form of the war in Judæa, which called for an energetic and able leader, such as Vespasian had shown himself under Claudius in Britain, and at the same time one whose humble origin made it safe to trust him with a great army. On becoming emperor he acquired the prestige and sanctity which were lacking in a parvenue prince by performing miracles,[84] but how little his head was turned is shown by the last joke of the inveterate humorist, uttered on his death-bed, "Woe's me! methinks I'm turning into a god."[85] Finally we have the fine picture of the sturdy old man struggling to rise and meet death on his feet, as an emperor should,[86] and dying in the arms of his attendants.

Although Suetonius doubtless intended his method to be strictly impartial, and though it would have been more nearly so in the hands of a more critical writer, it does not in reality give us a fair estimate of the emperors. To realize this we have only to imagine the biography of some prominent man of our own day, made up of praise and censure drawn indiscriminately from the organs of his own party and those of the opposition, and presented with little or no comment. So far from accepting his statements at their face value, the critical reader will hardly regard the judgment recently expressed by Professor Botsford as too severe:[87] "in the case of an author like Suetonius the student of history may begin his examination by rejecting, at least provisionally, everything that could not have been known to the public at the time of its alleged happening or that is not vouched for by trustworthy documents. This process of sifting will leave a substratum of facts on which the investigator may

[82] Calig., 23, 2.
[83] Calig., 53, 2.
[84] Vesp., 7, 2.
[85] Vesp., 23, 4.
[86] Vesp., 24.
[87] *Amer. Jour. of Phil.*, XXXIV., p. 88.

proceed according to his judgment to build his historical edifice." It is one of the weaknesses of Ferrero's interesting and suggestive work, that he now accepts the testimony of Suetonius and now rejects it as mere gossip, according to its relation to his own theories.

One cannot but wonder somewhat at the freedom with which a member of the imperial household[88] ventured to speak of the emperors of the past. It must be remembered, however, that Hadrian had no family connection with the men of whom Suetonius writes, and that the failings and vices of his predecessors made the virtues of the reigning prince more conspicuous. But consistently with the general plan of the work, we find no trace of that contrast of the evil days of the past with the happy present which appears in the third chapter of the "Agricola." We have only the very moderate remark at the end of the "Life of Domitian," where after speaking of the dream from which that emperor inferred a happier condition of the state after his death, Suetonius says: "sicut sane breve evenit, abstinentia et moderatione insequentium principum."

Suetonius has been stigmatized as a scandal-monger and a man of prurient mind. The former charge seems not to be justified. He did, it is true, collect all the damning details which seemed to him interesting, but even in the case of emperors like Caligula and Nero he is equally conscientious in assembling all that can be said in their favor. The so-called scandal-mongery is, in fact, a feature of the development of realism in the writings of the imperial period[89] and of an interest in all the details of the private life of prominent men.

The second charge is based in part on the accounts of the sexual habits of the emperors, and in part on the fact that he wrote a work "On Famous Courtesans." The latter argument may be dismissed as unconvincing, since the work has not come down to us and we have no means of knowing how the subject was treated. The former no more convicts him of pruriency than the amusing stories and witticisms which he has diligently collected justify us in crediting him with a sense of humor, in spite of numerous indications to

[88] The "Cæsars" was published while Suetonius was Hadrian's secretary, apparently in 120.

[89] See H. T. Peck, "Julius and Augustus," introd., pp. v ff.

the contrary.[90] In reality these details are presented with the same judicial coldness which is characteristic of his work in general, and he cannot be called obscene in the sense in which we may apply that term to Martial and Juvenal, for example. His discussion of such matters is undeniably plain and frank, but it must be remembered that the ancient conception of *pudicitia* was very different from the modern one.[91] Moreover the feeling which to-day leaves certain of his chapters in the original Latin or expresses them in veiled language is of comparatively recent date. Holland, for instance, in 1606 found no embarrassment in translating Suetonius into the frankest English and dedicating his book "To the Right Honorable and Vertuous Ladie Harington."

While it is obvious that we must regard the "Lives of the Cæsars" more or less in the light of a work of fiction, it deserves to be read as our best and most characteristic specimen of Roman biography, albeit with an open mind and in a spirit of scholarly scepticism.

[90] This subject will be discussed at another time.
[91] See Julius, 49, 1.

THE CONTROL OF TYPHOID FEVER BY VACCINATION.

By MAZYCK P. RAVENEL, M.D.

(*Read April 18, 1913.*)

The discovery of the prevention of disease by the use of attenuated cultures of bacteria is due to Pasteur, who, in 1879, discovered that when a chicken was inoculated with a weakened culture of the chicken cholera bacillus it became sick but soon recovered and thereafter could resist injections with the virulent germ without injury. Following Pasteur's suggestion, those methods by which we protect against disease through the use of attenuated cultures are spoken of as "vaccination," and the materials "vaccines," in honor of Sir Edward Jenner, who discovered vaccination against small-pox. Pasteur's later success in immunizing animals against anthrax by similar methods led to experiments on laboratory animals looking toward immunization against typhoid fever.

In 1896, Doctor (now Sir) Almroth E. Wright inoculated two men with killed cultures of the typhoid germ. Pfeiffer and Kolle in the same year immunized two men and made a subsequent study of the changes produced in the blood. In 1897, Dr. Wright published the results of his inoculations made on eighteen men, which convinced him that the method was a practical one in the prevention of the disease. Dr. Wright soon after tried it in the British army in India, but the outbreak of the Boer War gave him his first opportunity to carry it out on a large scale. The results were hard to collect accurately and opinions differed greatly as to the ultimate success of the method. Dr. Wright, however, believed that the incidence of the disease was diminished about one half, and that the mortality was favorably influenced to even greater extent.

We now understand some of the reasons for the varying effect of the vaccine. At that time the cultures were heated to a temperature of 60° C. in order to destroy their vitality. It has since been

shown that this amount of heat injures or destroys to a great extent the power of the germs to produce a good response in the formation of those substances on which the body depends for its protection. At the present time the cultures are killed by heating to 53° C.

It was tried next on a large scale in the German Colonial army during the Hereros campaign of 1904–07. The reports of this expedition show that the percentage of typhoid fever among the uninoculated was almost 10 per cent., whereas among the vaccinated it was only a trifle over 5 per cent. Further than this, the figures show that 76.01 per cent. of the inoculated who contracted the disease had mild or moderately severe cases, with the fatal cases numbering 6.47 per cent., whereas only 61 per cent. of the uninoculated had light or moderately severe cases, while the mortality reached 12.80 per cent. It was further shown that among the vaccinated 60 per cent. of the fatal cases occurred in those who had received only one dose of vaccine, 33 per cent. in those who had received two doses, and only 8⅓ per cent. in men who had received the three inoculations (Russell).

The value of the method has been made the subject of study by a number of commissions appointed by various governments all of which have made favorable reports. After careful consideration, anti-typhoid vaccine was introduced in the United States army as a voluntary measure in 1909. The favorable results were so striking that in 1911 it was made compulsory for all officers and enlisted men under the age of forty-five years. The most striking example of its efficacy is afforded by a comparative study of two bodies of soldiers, approximately equal in numbers, living under similar conditions during the same period of the year, and in much the same climate, one stationed at Jacksonville, Fla., in 1898; the other at San Antonio, Tex., during the maneuvers of 1911. At Jacksonville there were 10,759 men, with 2,693 cases of illness known, or believed to be, typhoid fever, and 248 deaths. At San Antonio there were 12,801 soldiers with only one case of typhoid fever, which resulted in recovery. During the same time there occurred in the city of San Antonio forty-nine cases of typhoid fever with nineteen deaths, showing that the infection was prevalent in that community and demonstrating that the difference in the incidence of typhoid fever

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was almost certainly due in large part to vaccination. As the troops had considerable freedom in visiting the city, this conclusion is rendered all the more certain.

Preparation of the Vaccine.

The method of preparation varies slightly in different laboratories, but the following is probably most often followed.

Pure cultures of the typhoid bacillus are grown on slanted agar, preferably in flat bottles, which give a large surface for culture. At the end of forty-eight hours the bacilli are scraped off and suspended in normal salt solution. The suspension is then heated for one hour to a temperature of 53° C., preferably in a water bath, after which it is standardized by comparing it with normal blood. Equal parts of normal human blood and the suspension of bacteria are mixed, and oftentimes diluted in order to facilitate counting. Spreads from the mixture are made on slides, stained, and a large number of fields (usually one hundred) examined, and both red blood cells and bacteria are counted. The average number of blood cells per field and the average number of bacteria per field are then compared. The normal blood count is taken at five million red cells for each cubic millimeter. Knowing this, it is easy to determine the number of germs per cubic centimeter. The vaccine is then diluted with normal salt solution until the mixture contains one thousand million bacilli per cubic centimeter. If it is to be sent out to physicians in general practice, it is better also to make a further dilution of the suspension to five hundred million per cubic centimeter for the first injection so that the size of the dose may be kept uniform while the number of bacteria contained in the dose is varied. The vaccine may be preserved for considerable lengths of time by the addition of one fourth per cent. of lysol, or carbolic acid. When kept in a cool and dark place its properties are maintained uninjured for at least three months.

It is also advised that the material should not be used until it is three weeks old, as freshly prepared vaccine apparently is more apt to give severe local reactions than that which is older.

Polyvalent Vaccine.

At the present time many laboratories are using what is called polyvalent vaccine; that is, one made of a number of pure cultures derived from different sources, mixed together in approximately equal proportions. Thus, in preparing vaccine for the immunization of the French soldiers in Morocco cultures were obtained from cases of typhoid fever occurring in that country. Some bacteriologists also add to the vaccine cultures of the para-typhoids, A and B. At the Laboratory of Hygiene of the University of Wisconsin it is our invariable practice to prepare polyvalent vaccine.

Vincent, who has prepared most of the vaccine used in the French army, uses twelve different strains. After full growth has been obtained, the bacteria are autolized in salt solution with frequent shaking, and killed by being subjected to the action of sulphuric ether.

Dosage.

In America the dose universally employed is that advised by the army. Three doses are given ten days apart. The first dose consists of five hundred million bacteria, the second and third one thousand million each. The injections are made preferably in the upper arm about the insertion of the deltoid muscle, and are given under the skin and not into the muscles. The skin is sterilized with iodine, and the sterile needle is thrust through the area thus prepared. It is customary to vaccinate about four o'clock in the afternoon so that any reaction which takes place will occur during the night and be practically over with by the next day.

The use of alcohol in any form is prohibited, as even moderate amounts seem to increase the severity of both local and general symptoms.

No special precautions are necessary and the vaccine does not usually interfere with the ordinary vocations of life. Occasionally slight chilliness and even rigors may occur combined with headache, general malaise, and sometimes distinct nausea. Locally, there is an area of redness and tenderness, the worst of which is over with within twenty-four hours. Suppuration never occurs.

The vaccine is well borne by women and children, but the dose

for children should be smaller than that given to adults in proportion to their weight, the dose given being that proportion of the adult dose which the weight of the child bears to the average adult weight, namely, one hundrd and fifty pounds.

Major Russell reports that of three hundred and fifty-nine children vaccinated in no case had any bad effects been observed, and no case of typhoid fever had occurred amongst them up to the time of his report. In approximately one hundred and twenty-nine thousands injections in adults there were only six tenths of one per cent. of severe reactions. Of these, three tenths of one per cent. followed the first injection.

The vaccine should not be given to anyone running a temperature. Vincent has shown that in persons suffering from malaria the occurrence of a paroxysm is oftentimes precipitated by the giving of a dose of vaccine. In the enormous practice in the United States army the only serious result which has been observed occurred in a man suffering from an unrecognized incipient tuberculosis. The rule, therefore, is to be sure that the person about to be inoculated has a normal temperature.

General Application of the Method.

It is evident that the use of vaccine is particularly applicable to armies or other large gatherings of men who are apt to be in temporary quarters deprived of the usual sanitary arrangements for the disposal of sewage. However, the use of the vaccine has a very much wider range than this, being of great value in the suppression of local epidemics. A typical case of its use under these circumstances will be mentioned.

A water borne epidemic occurred in Avignon, France, a town with a population of 49,000, in 1912. Six hundred and forty-four cases with sixty-four deaths were reported, but it is certain that the total number of cases reached 1,500. The garrison of the town consisted of 2,053 men. Of these, 1,366 were vaccinated; 687 not vaccinated. Among the unvaccinated there occurred 159 cases of typhoid fever with 21 deaths; while not a single case occurred amongst those who had been vaccinated. All lived under the same

conditions, drank the same water, ate the same food, and did the same work.

In the State of Wsiconsin, the bacteriologist of the State Laboratory of Hygiene has administered the vaccine in two outbreaks, one occurring in a county hospital, and the other in a small village. At the institution one hundred and six persons were vaccinated. One case of typhoid fever occurred amongst those who received the vaccine, but within such a short time that it was evident that the person had been infected before vaccination was practiced. The case was atypical and of the mildest type, resulting in recovery, showing that the vaccine exercises a favorable effect when given during the period of incubation. During an epidemic in the town of Warrens, Wis., one hundred and sixteen persons were vaccinated. The epidemic ceased at once, and since that time only one case of typhoid fever has been reported among the vaccinated.

The method is of the greatest use in institutions, especially hospitals. It has long been known that nurses were more liable to typhoid fever than other people, as the result of direct exposure.

Dr. Spooner began the inoculation of nurses in the Massachusetts General Hospital, and reported that for the first time in the history of the institution no nurses had suffered from typhoid fever during the year. The practice has, since October, 1912, been extended by him to twenty-three hospitals in Massachusetts. In all, 1,361 individuals have been treated. In the same hospitals there have been six hundred and seventy-four persons exposed but not vaccinated. Among the vaccinated there have been three cases of typhoid and para-typhoid fever. Among the uninoculated there have been seventeen cases of typhoid and para-typhoid fever. It is evident that a large amount of protection was furnished by the inoculation among those especially exposed to the disease.

In the State of Wisconsin we advise that whenever a case of typhoid fever occurs in a family the other members of the family shall receive the protective inoculations. It is impossible to give exact figures of the results, but several very striking instances have been reported to us.

In Watertown vaccination was advised for the husband of a woman suffering from typhoid, and two trained nurses who were in attendance. One of the nurses refused to be vaccinated, saying that she was immune. About three weeks after leaving the case she went down with a severe case of typhoid fever, and was ill for several weeks. The husband and other nurse remained well.

The vaccination has been carried out also to a large extent in the National Guard of Wisconsin. This is still on a voluntary basis. In 1912 a large number of troops submitted to the inoculations, but many refused them. Some of those who declined were taken sick with typhoid fever soon after reaching home. We have not been able to trace any case among those who received the full vaccination.

Another condition in which the use of anti-typhoid vaccine is likely to prove of great service is in the treatment of typhoid bacillus carriers. During the last few years many cases have come to light in which individuals have been carrying the typhoid fever germ, and have been discharging it from their bodies for longer or shorter periods of time; such persons are known as "carriers." The most noted of these cases, "Typhoid Mary" in New York, is well known to the general public. Another striking example came to light on the steamship *Acme* sailing from San Francisco. So many cases of typhoid fever occurred among the sailors on this vessel that she obtained a bad name as the "fever ship," and it was difficult to secure good crews. The treatment of such cases has been a puzzle to the medical profession, and it seemed impossible to keep these persons in hospitals or under quarantine indefinitely. It has been found, however, in a number of cases such as those reported by Brem, and by Currie and McKeon, that the bacilli rapidly disappeared from the discharges of the body after administration of a vaccine made from the particular strain of typhoid germs recovered from the patient—what is known as an autogenous vaccine.

There are nineteen cases of carriers recorded in literature that have been treated with typhoid vaccine. Fourteen of these were successful; five were failures, though two of the latter were helped for a time.

In conclusion, I think we are justified in saying that in anti-typhoid vaccination we have an efficient method for the control of the disease under many and varying circumstances. It can never, however, take the place of sanitation, the proper disposal of sewage, and provision of safe water supplies.

WISCONSIN STATE LABORATORY OF HYGIENE,
MADISON, WIS., April, 1913.

THE TREATY OBLIGATIONS OF THE UNITED STATES RELATING TO THE PANAMA CANAL.

By CHARLEMAGNE TOWER.

(*Read April 17, 1913.*)

I beg leave to call to the attention of the society a subject which has been considerably discussed of late, in Congress and throughout the country, and cannot be considered in any sense to be new; but, in spite of this fact, and of a certain familiarity which it has acquired in men's minds from frequent mention, I am inclined to the thought that it can scarcely be too plainly or too forcibly brought before the sober consideration of the American people,—the international obligations undertaken by the United States in the treaties relating to the Panama Canal.

The subject of a canal across the narrow strip of land that joins the two continents is one, indeed, that is nearly contemporaneous with the discovery of America; for its advantages made themselves evident even to the earliest explorers and navigators, who, upon returning to Spain, in 1528—more than 150 years before William Penn entered the Delaware,—presented to the Emperor Charles V. a plan for the opening of a waterway through the Isthmus of Panama; a project that never was lost sight of and which acquired greater importance to us, both from our political and commercial point of view, after our separation from Great Britain and the establishment of our independent nationality.

In 1826, Mr. Clay, then Secretary of State, wrote, in connection with a Congress at Panama:

> "A cut or canal for purposes of navigation somewhere through the isthmus that connects the two Americas, to unite the Pacific and Atlantic Oceans, will form a proper subject of consideration. That vast object, if it should be ever accomplished, will be interesting, in a greater or less degree, to all parts of the world."

We were not in a position at that time to think of undertaking such a work ourselves, though our government was alive to the opportunity and wished to participate in the advantages that would arise from a canal; and Mr. Clay added:

"If the work should ever be executed so as to admit of the passage of sea-vessels from ocean to ocean, the benefit of it ought not to be exclusively appropriated to any one nation, but should be extended to all parts of the globe upon the payment of a just compensation or reasonable tolls."

The progress of events and the growth of our importance as a nation enlarged the interest of the people of the United States in the passage through the isthmus, which was taken up in the House of Representatives in compliance with a memorial from the merchants of New York and Philadelphia in 1839. A resolution was adopted by the House that the President should be requested:

"To consider the expediency of opening or continuing negotiations with the governments of other nations, and particularly with those the territorial jurisdiction of which comprehends the Isthmus of Panama, for the purpose of ascertaining the practicability of affecting a communication between the Atlantic and Pacific Oceans, by the construction of a ship canal across the isthmus, and of securing forever the free and equal right of navigating such Canal to all nations."

A treaty was entered into, seven years later, in 1846, between the United States and the Republic of New Granada, which was the first effective step taken by our government in the direction of the actual transit across the isthmus and of our participation in its construction and maintenance of way. This was a treaty of peace, amity, navigation and commerce with New Granada, and was continued in operation by the Republic of Columbia into which that state was subsequently transformed, and it is to this agreement, entered into by us during the administration of President Polk, through an immense amount of negotiation and correspondence that has taken place since between ourselves and other governments, particularly those of the Central and South American republics as well as Great Britain and France, that may be traced the origin of the interests and claims under which the United States have constructed the canal and are in control of the territory of the canal zone on the isthmus to-day. The treaty extended to the citizens of the

United States all the privileges and immunities of commerce and navigation in the ports of New Granada that are enjoyed by the Granadian citizens themselves, and the government of New Granada guaranteed to the United States, "that the right of way or transit across the Isthmus of Panama upon any modes of communication that now exist or that may be hereafter constructed, shall be open and free to the Government and citizens of the United States." In return for these favors the United States guaranteed: "positively and efficaciously, to New Granada, the perfect neutrality of the isthmus, with the view that the free transit from the one to the other sea may not be interrupted in any future time while this treaty exists"; and, in consequence, the United States guaranteed, "in the same manner, the rights of sovereignty and property which New Granada has and possesses over the said territory."

Therefore we had acquired a controlling influence at Panama which enabled us to play so prominent a part that we might begin to make effective plans for the construction of a canal; whether we should decide to build it ourselves, or whether the work should be done by others, it was quite certain that no canal could be made without our consent. We had secured the constant enjoyment to ourselves of the commercial privileges enjoyed by the inhabitants of New Granada, and as New Granada was a weak power we made the stipulation in return for the favors that she had shown to us that the United States government with its superior strength would protect New Granada in her rights of ownership on the Isthmus of Panama and would guarantee that she should always maintain her sovereignty over that territory. We failed afterwards to carry out our agreement in this respect; and the protest of Colombia, taken upon its merits as a matter of international law, is very serious,—but that belongs to another subject.

Our attitude was made plain at that time by the message with which the President submitted this treaty to the Senate, in 1847, for its approval and ratification, in which he announced formally the policy of the United States to develop the communication through the isthmus for the benefit of the commerce of the world at large.

Mr. Polk declared that the treaty did not "constitute an alliance

for any political object, but for a purely commercial purpose, in which all the navigating nations of the world have a common interest."

"The ultimate object is to secure to all nations the free and equal right of passage over the isthmus. If the United States should first become a party to this guaranty, it cannot be doubted that similar guarantees will be given to New Granada by Great Britain and France."

If the proposition should be rejected by the Senate, the President said, "we may deprive the United States of the just influence which its acceptance might secure to them, and confer the glory and benefits of being the first among the nations in concluding such an arrangement upon the government either of Great Britain or France."

But, at the time that this treaty was made, Great Britain claimed dominion in certain parts of Central America over which she exerted authority and of which she was in actual possession; these were the territory extending along the coast of Guatemala, called Belize or British Honduras, including an island called Ruatan and other Bay Islands, and she asserted a protectorate over a long stretch of Nicaraugua inhabited by the Mosquito Indians, called the Mosquito Coast. She had a more direct claim upon and closer personal relation with the people of Central America than we had,—her occupation of British Honduras dating back at least to a treaty which she made with Spain in 1786.

In pursuance of our policy, however, of creating a neutral territory at the isthmus, and of preventing the establishment there by any single foreign nation of exclusive control, we proposed, in 1850, that Great Britain should unite her interests with ours in order that not only the canal should be built upon fair and equitable terms, "but that its construction should inure to the benefit of all nations and should offer equal opportunity to the commerce of the world; and for this purpose we invited Great Britain, and she consented, to enter into a convention with us with the intention of setting forth and fixing the views and intentions of both governments, with reference to any means of communication by ship canal which may be constructed between the Atlantic and Pacific Oceans by way of the river San Juan de Nicaragua, to any port or place on the Pacific

Ocean." This was the Clayton-Bulwer Treaty, which was signed at Washington on the nineteenth of April, 1850, by Mr. John M. Clayton, then Secretary of State, and Sir Henry Lytton Bulwer, British Minister to the United States. By it:

"The Governments of the United States and Great Britain declare that neither the one nor the other will ever obtain or maintain for itself any exclusive control over the ship Canal, will not fortify, or colonize, or exercise any dominion over Nicaragua, Costa Rica, the Mosquito Coast, or any part of Central America; also, that neither Great Britain nor the United States will take advantage of any intimacy or alliance that it may have with any government through whose territory the Canal shall pass, for the purpose of acquiring or holding any rights or advantages in regard to commerce or navigation through the Canal which shall not be offered on the same terms to the Citizens or subjects of the other."

The treaty having thus provided for the joint action of Great Britain and the United States, and having agreed that the two governments should give their support and encouragement to any persons or company who might first offer to begin the canal with the necessary concessions and capital, the two contracting nations included in it the following statement:

"The Governments of the United States and Great Britain having not only desired, in entering into this Convention, to accomplish a particular object, but also to establish a general principle, they hereby agree to extend their protection, by treaty stipulations, to any other practicable communications, whether by canal or railway, across the isthmus which connects North and South America, and especially to the interoceanic communications, should the same prove to be practicable, which are now proposed to be established by the way of Tehuantepec or Panama";—it being understood—"that the parties constructing or owning the same shall impose no other charges or conditions of traffic thereupon than the aforesaid Governments shall approve of,—and that the same canals or railways, being open to the citizens and subjects of the United States and Great Britain on equal terms, shall also be open on like terms to the citizens and subjects of every other State which is willing to grant thereto such protection as the United States and Great Britain engage to afford."

Thus, the Clayton-Bulwer treaty became the foundation for the understanding between the United States and Great Britain and provided for an absolute equality between them in regard, not only to the protection which they united to give to any interoceanic communication that should be established, but also formally declared that

both governments should approve of any charges or conditions of traffic,—that is to say, tolls,—which might be imposed, and that no such tolls should be imposed, in fact, which had not the approval and consent of both governments.

The United States government considered that it had entered into an agreement that was both just and equitable toward both parties, as a definition of the rights and duties of each and a basis upon which the isthmian canal should be built as a benefit to the commerce of the world.

And further, we not only held ourselves to be bound by the stipulations of this agreement, but we called upon Great Britain to sustain her part of it by a very strict interpretation of the law, quite beyond what the British Cabinet had expected in entering into the engagement, and a good deal more than it was willing at first to concede; for we contended that by the provisions of the treaty both nations had promised not: "to make use of any protection or alliance which either has or may have with any state or people for the purpose of fortifying or colonizing Nicaragua, Costa Rica, the Mosquito Coast, or any part of Central America, *or of assuming or exercising dominion over the same.*" And we called upon the British government, under this provision, not only not to extend its political influence in Central America but also to give up such claims as it might already have acquired in British Honduras, the Mosquito Coast and the islands of the sea.

This was not at all what Great Britain had understood to be her position under the treaty, and Lord Clarendon declared, (1854) that the contracting parties did not intend to include within its action "either the British settlement in Honduras nor the islands known as its dependencies," that whatever claims or influence Great Britain may have had there previously should remain undisturbed,—that the only question which might arise in regard to this was one relating to the boundary line of Honduras,—as to what was British Honduras and what was not.

"To this settlement and these islands the treaty we negotiated was not intended by either of us to apply,—and the British government is more warranted in this conclusion from the fact that the United States sent a

Consul to the settlement, in 1847, which Consul had received his exequatur from the British government which was a recognition of the British claim.

"But, on our side," Mr. Marcy, Secretary of State, declared in answer to this, (1856), "Great Britain had not any rightful possessions in Central America, and at the same time, if she had any, she was bound by the express tenor and true construction of the Clayton-Bulwer Treaty to avacuate them, so as to stand on precisely the same footing in that respect as the United States."

This defines our position in regard to the affairs of the isthmus; it insists that Great Britain shall place herself upon an exact equality with us; that she must give up any claims or privileges in which we did not share, in order that we may be precisely alike; but it marks also our obligation toward Great Britain,—for whilst we insisted that she should be on an equal footing with us, we promised that we should be upon an equal footing with her. We won our case and England, giving up the Mosquito Coast and the islands, came ultimately to our understanding, because of the Clayton-Bulwer Treaty;—but the provision of the treaty was that: neither the United States nor Great Britain should exert any influence that either may possess, "for the purpose of acquiring directly or indirectly, for the citizens of the one any rights or advantages in regard to Commerce or navigation through the said Canal which shall not be offered on the same terms to the citizens or subjects of the other."

General Cass said, (1858):

"What the United States want in Central America, next to the happiness of its people, is the security and neutrality of the inter-oceanic routes which lead through it. If the principles and policy of the Clayton-Bulwer Treaty are carried into effect, this object is accomplished."

It is to be observed that there are two distinct points of agreement which are set forth in this Treaty as well as in all of the voluminous correspondence that had taken place in regard to it,—which points of agreement have never been lost sight of as the basis of the negotiations relating to the Canal across the isthmus; namely the neutrality of the canal itself and the absolute equality between the United States and Great Britain in connection with it. We demanded it from the start and Great Britain has acceeded to

our demand with that principle in view, which has never been changed.

She was willing to join with us in building the canal, or she was willing that we should build it alone. And when after a good many years of delay we announced to her that we were in a position to undertake the work, and we made suggestions to her looking to that result, she agreed to make a new treaty with us, to supersede the old one, in order that the intended benefits might be secured and the work should progress.

The new treaty was signed in November, 1901, by Mr. John Hay, Secretary of State, and Lord Pauncefote, the British Ambassador, whence it has since become widely known as the "Hay-Pauncefote Treaty."

By this contract the two powers

"Being desirous to facilitate the construction of a ship-canal to connect the Atlantic and Pacific Oceans, by whatever route may be considered expedient, and to that end to remove any objection which may arise out of the Convention of the nineteenth April, 1850, commonly called the Clayton-Bulwer Treaty, to the construction of such canal under the auspices of the Government of the United States, without impairing the 'general principle' of neutralization established in Article VIII. of that Convention, agreed that: The present Treaty shall supersede that of April 19, 1850. That the canal may be constructed under the auspices of the Government of the United States,—and that, subject to the provisions of the present Treaty, the United States shall enjoy all the rights incident to its construction, as well as the exclusive right of providing for the regulation and management of the canal. And, in order to make plain the understanding between ourselves and the British Government with whom we were dealing, we made this specific stipulation: (Article III.).

"The United States adopts, as the basis of the neutralization of such ship-canal, the Rules, substantially as embodied in the Convention of Constantinople (28 October, 1888), for the free navigation of the Suez Canal, that is to say:

"1. The Canal shall be free and open to the vessels of commerce and of war of all nations observing these Rules, on terms of entire equality, so that there shall be no discrimination against any such nation, or its citizens or subjects, in respect of the conditions or charges of traffic, or otherwise."

This is not an obscure subject. It is a treaty into which the United States entered openly and freely with Great Britain,—a treaty based upon all that had gone before, both in our correspondence and

our engagements under which Great Britain placed herself and her interests upon an equality with us and with our interests in Central America. The situation is one that we have created for ourselves.

It is not a question as to whether we made a good bargain or a bad one, but it is a matter of the greatest importance to the American people that the Government of this country shall fulfill its engagements and carry out always and in every particular its international obligations.

PHILADELPHIA,
April 17, 1913.

A COUNSEL OF PERFECTION: A PLAN FOR AN AUTOMATIC COLLECTION AND DISTRIBUTION OF A STATE TAX FOR HIGHER EDUCATION.

By J. G. ROSENGARTEN.

(*Read April 17, 1913.*)

The example of the western state universities suggests a similar organization for other states. Here in Pennsylvania the University, dating from 1740, when under the inspiration of Whitefield, the plan of a school was first mooted, has outgrown its modest endowments. Biennially it goes to the legislature to ask help to carry on its work. In the interval it appeals to its alumni and friends for help to meet its pressing needs, higher salaries, a larger teaching force, and more buildings and appliances for its multifarious educational needs.

What is true of the University of Pennsylvania is true of all other universities and colleges of Pennsylvania, and of the East and South, and no matter how large their endowments and income, each and all require more money to keep pace with the growing expenses of higher education in the modern university.

It needs no apology to broach the matter here, for Franklin founded both the American Philosophical Society and the University of Pennsylvania. In fact after the Revolution the charter of his College of Philadelphia was taken away, and a Charter given to the University of the State of Pennsylvania, and the constitution affirmed the duty of the state to help it. Later the charter of the college was restored, and still later the college and the university were united in the University of Pennsylvania, and it has grown to its present great estate under that charter and that name.

From time to time the state has aided it, and private munificence has enabled it to provide the splendid buildings in which it is now housed, with College and Law and Medical Departments, and to

maintain the Towne Engineering School, and the Wharton School of Finance and Economy, and the Zoölogical and Dental and Veterinary Schools, and a long list of endowed Professorships and Fellowships and Scholarships and prizes. With all these, and the other resources of the university, there is still an annual deficit which must be met. To do so would require an additional endowment sufficient to provide an income of half a million dollars to meet the needs of the university. How to provide this is a question that taxes the university authorities and exacts time, thought and anxiety of provost, trustees, faculty and alumni, when they ought to be free to give attention to the work of instruction and to raising the standard of education in all its departments.

Illinois, Indiana, Iowa, Montana, Wisconsin, are among the western states which have state universities. In their state constitutions provision is made for an automatic assignment of a small part of the state taxes for their support. Thus all appeal to the state legislature for support is made unnecessary. In Wisconsin, and in many other universities, colleges, etc., the United States Land Grant is made part of the endowment of the state university, and for agricultural and technical schools. Iowa has recently put all its educational institutions under a single governing board. All the western universities have out of the increasing wealth and revenues of their states provided incomes growing in proportion to their needs, and their activities keep pace with them. University extension lectures carry their teachers to every part of their state, and every branch of education is fostered under intelligent guidance, with university men spreading the influence for higher and better education.

A constitutional convention is soon to be called in Pennsylvania. There a plan should be formulated, submitted and discussed for a reorganization that may strengthen institutions of higher education in Pennsylvania. The plan and method of securing automatically a portion of the state revenue for the purpose of education are now in force in twenty one states, so that there is little novelty in the idea, for it has been in practical operation in all of them, with various differences, and yet almost uniformly successful results. Only recently, in acknowledging a paper on German Universities, that

Nestor of both American and German universities, the Hon. Andrew D. White, of Cornell, wrote:

"It is doing a duty to the country to call attention to the evils caused by the scattering of resources among so large a number of institutions bearing the name of 'University.'

"The worst affliction of our whole existing system is the fact that such a multitude of institutions which ought to be called 'Colleges' are pretending to do University work, while they are in no condition to do the duties worthy of that name.

"What the country needs is a concentration upon a smaller number of Universities, with a large number,—no matter how large indeed,—discharging a function akin to that of the 'Gymnasia' in Germany, which might very honorably be called 'Colleges.' An example of a better practice may be found in some parts of New England, where institutions, some of which were up to a recent time called 'Universities,' have become frankly 'Colleges.'

"We are about to have Universities which will give us high rank throughout the World, and among them especially the State Universities of the West, as well as some that have been established upon large foundations in the eastern part of our country.

"As to the Western State Universities, their progress is simply amazing. There has been developed an honorable pride in them by their respective states, and this has been deepened by a very honorable rivalry between sundry commonwealths, as for example Michigan, Wisconsin, and Minnesota, which has resulted in a magnificent fruitage.

"While the standard of scholarship is kept deplorably low in some of the smaller Universities, it has been steadily rising in many of the better endowed institutions. The increase of lectures by distinguished foreign professors at various American Universities of the better sort, will be productive of great good. Cornell, for example, is about to have an extended course of lectures on American History, by a renowned Oxford Professor upon the Goldwin Smith Foundation. Who would not gladly exchange our scattered flock of Universities and Colleges, running up into the hundreds, for the twenty two Universities of Germany?"

There too the important cities of Hamburg and Frankfurt are about to coördinate all their existing institutions of science, art and literature, into great metropolitan universities, retaining all the useful elements of successful and thorough education and training, and elevating the standard of work.

Against the twenty-four universities, and nine technical schools, of Germany, the last report of the Commissioner of Education of the United States reported nearly five hundred universities and

colleges for men, and one hundred and thirty for women, and over one hundred and fifty technical schools, nearly one hundred law schools, and proportionately numerous medical, dental, pharmaceutical, and other allied special schools. With this enormous disparity in numbers, it is easy to see why the German schools and universities do their work thoroughly and well.

The state regulations and examinations for the bar and for medicine and various other professions and employments, show the need felt for something more than the diploma of university, college or technical school.

A state university, representing, in its government, all the institutions of instruction in education, in all its varieties, general and technical, would give strength to each and all of the schools affiliated with it, and its degrees, awarded on their recommendation, would be greatly enhanced in value.

The first step in Pennsylvania would be to take advantage of the proposed constitutional convention, and introduce into the new state constitution,

First.—Provisions for an automatic appropriation of part of the revenue of the state, to higher education, to be distributed in the maintenance of a University of the State of Pennsylvania, and allied colleges and technical schools, thus going back to the wise provision of the Constitution of 1779.

Second.—Legislative power to strengthen and increase the power of the College and University Council, with the Governor, the Superintendent of Public Instruction, the Attorney General, State Officers, ex officio, and the presidents of the University of Pennsylvania, Pittsburgh, Lehigh, Bucknell, and of Washington, Jefferson, State, Franklin & Marshall and other colleges and other institutions, the members.

Third.—To give that board power to distribute the state educational fund among the state universities, colleges, technical schools and other institutions of learning, science and art, on such terms as to numbers of teachers and students, standards, and other conditions as may be prescribed by the college and university council.

Fourth.—To make all universities, colleges, technical schools and

institutions for higher education, branches of the university of the state, retaining their names, organization, endowments, etc., but requiring annual returns of all the details of numbers, income, work, etc., on a uniform basis, with provision for inspection, audit, examination, so thorough that the highest standard of efficiency may be secured and maintained, under the penalty of losing any claim to the income from the state education fund; the council to have the right and privilege of approving and recommending the degrees in course conferred by the university and other universities and colleges of the state, with power to revoke or modify charters of any affiliated institution for cause.

Fifth.—The college and university council to have power to consolidate existing institutions working in one district or multiplying the work that could be better done by one strong institution, thus giving to the state one or more medical, legal, technical or other schools, in lieu of an unnecessarily large number of small schools, weakened by competition, lessening standards, and not really serving the state, owing to insufficient means and inefficient methods.

Sixth.—Uniting with the state university, libraries, university extension work, scientific and art and technical schools and museums, in such a way that all unnecessary duplication may be prevented, and higher education ensured through uniform grants from the state educational fund.

Seventh.—The college and university council to have the inspection of the normal schools, in such a way as to unite in close sequence the methods of education, from the public and private schools, the normal schools, etc., through the colleges and technical schools and up to the university.

Twenty states have made provision in their constitutions for automatic collection and distribution of a small part of the revenue of the State to aid in the work of education of its people, and Pennsylvania should make similar provision in its new constitution. It would increase the efficiency of its institutions of learning, relieve the legislature of a task which is no part of its proper duty, free the trustees and officers and faculties of our universities and colleges from the necessity of going to the legislature and the governor of

the commonwealth, give them a right to a part of the state revenue thus set apart for education, elevate the standards and enhance their efficiency, by allying them with the University of the State of Pennsylvania, and give their degrees a position recognized through the state and beyond it.

This may be a counsel of perfection, but none the less well worth discussion and careful consideration by the American Philosophical Society, true to its purpose of promoting useful knowledge. What can be more useful than to know how best to bring to bear on education the means and methods of securing that which is best fitted to prepare men and women to be good citizens, to teach them all that is necessary, to secure them the best schools for every profession and occupation, and to reform existing institutions of learning, so that they may do the greatest good to the largest number?

Make the state supply from its plethoric treasury, the money required for higher education, as it does for secondary and elementary schools, and then the distribution may be safely put into the hands of the state's college and university council, composed of state officers and the representatives of the universities and colleges and technical schools. Among them will be found men who will see that the state's money is well spent, with a proper distribution between buildings and maintenance, salaries and expenses incidental to instruction.

The state will supply through its *ex-officio* members and its trained inspectors due protection against undue expenditure of any kind.

The state college and university council may properly insist that wherever money is given for any special purpose, it shall be enough to provide for future maintenance, and not be, as it too often is the case today, a burden on income. There are plenty of reforms incidental to a reorganization of our institutions of learning, that will need the careful consideration of the state college and university council. A few years will serve to show how unnecessary duplication of work can be prevented, how neighboring colleges can be united into one strong college, how technical and professional schools can be strengthened by reducing their number, and increasing their

efficiency, how an exchange of professors may be systematized to the advantage of teachers and students, and how the standard of education may be raised.

Much will be done by the teachers themselves, and there can be no better inspiration to improve methods than to draw from the great body of men trained in the work of education, the results of their experience. Of course there will be impracticable suggestions and unworkable plans proposed, but those will all be submitted to the trained and experienced members of the State college and university council, and after full discussion, their judgment will choose the good and reject the bad. Plans and methods of teaching will be entrusted to experienced teachers, and the profession will rise in dignity and importance, as the work shows the good results of their experience, knowledge and ability. All this and much else can be accomplished if the new constitution of Pennsylvania makes the business of education a matter of state support and state government.

Andrew D. White, that Nestor of Higher Education in this country, first president of Cornell University, and always its inspiration, read a paper on "Advanced Education," before the National Education Association at Detroit, in 1874. Urgent arguments are brought forward for a reorganization of American universities and colleges and technical schools as part of the work of the state. Dr. White urges the necessity of careful public provision by the people for their own system of advanced instruction as the only republican and democratic method. Public provision, he said, is alone worthy of our dignity as citizens. It will stimulate private gifts and free them from the dogmas of living donors and dead testators. The nucleus of Cornell University was the national land grant, which has been supplemented by an increasing flow of private gifts to the endowment.

The state of Michigan made the national land grant the foundation of its great university, and has added to it from time to time with the best results. It has thus strengthened the whole system of public education throughout the state. The national grant and the state grant together have thus been united to make a great university, and provide the endowment of advanced instruction, and to coördi-

nate education from the primary school to the highest technical and scientific and classical and collegiate and professional training.

Such an example and that of twenty other States all point to the best way of meeting the general demand for a more regular and thorough public provision for advanced education, not through appeals to legislatures, to be subject to all the risks of overtaxed public bodies, but by a constitutional provision for a fixed, though small, percentage of the income of the State to be set apart for higher education and for all branches of education that ought to be maintained at the public expense, to be expended through the college and university council, made up of state officials and representatives of universities and colleges and institutions of advanced scientific and technical education. Established by law in 1895, it only needs increased power to do its best work.

Well directed public bounty, as President White says, stimulates private bounty. Generous men and women, seeing that the current needs of such institutions were provided by state revenue, would gladly give freely and largely for such special additions as may appeal to them. The alumni of universities will find new inspiration for their activity in giving, advising, and encouraging the growth and prosperity and advancement of their alma mater. Thus, nation, state, alumni and individual grants and gifts would be united to strengthen state institutions and enable them to give the highest literary, scientific and industrial instruction.

The same trend of educated opinion is found in other publication of the highest authority. In the 44th annual report of the Smithsonian Institute, that for 1889, Professor Herbert B. Adams's paper on the state and higher education gives the strongest facts and arguments in support of state aid. He points out that in colonial days Maryland began her educational history by paying a tobacco tax for the support of William and Mary College in Virginia. Vermont appropriated a township of land for Dartmouth College in New Hampshire. New Haven sent corn to the support of Harvard. In later times Michigan gave to the university one twentieth of a mill tax on every dollar of taxable property: Wisconsin one eighth of a mill; Nebraska three eighths of a mill; California one tenth of a

mill; and now the same rule holds in so many states that it may be described as the normal basis for state aid to higher education.

In the proceedings of the National Education Association there are abundant evidences that the leading and recognized authorities on education in this country take the same view.

In the report for 1900, President Swain, then of Indiana University, now of Swarthmore, gave a sketch of the history of the promotion of higher education by the state from early times until the present. He gives forty-five as the number of colleges and universities supported by the state, and points to seven representative state universities—California, Illinois, Kansas, Michigan, Minnesota, Nebraska, Wisconsin.

President Beardshear of Iowa State College of Agriculture, said there were 64 colleges or departments inaugurated by the Act of Congress of 1862, making land grants for the establishment of schools for mechanical and agricultural instruction.

Again at the National Education Association meeting of July, 1901, President Jesse of the State University of Wisconsin, read a paper on the "Function of the State University." He points out the opportunities for collaboration with state boards, bureaus and commissions, with a view to serious study of social and economic conditions.

Today and in and by our own university much is done for the state and the city, but as a matter of grace; make it the university of the state, and state and city would ask for help as a matter of right. Social and economical and legal problems would be attacked and solved. By coöperation with boards of education and state and local superintendents, the university would help to build up schools, from primary to normal, by trained inspectors, skilled examiners, lecturers, practical teachers. Colleges and higher technical schools should be brought into union with the university, all working towards the common end and aim, the best education of the largest number.

The university of the state should be in close touch with all the state boards, bureaus and commissions, the geological survey, the bureaus of health, education, forestry, mines, industries, all the innumerable functions and activities of the state. The university should help in the preparation of laws governing taxation, every

day growing more complex, and in every form of economic instruction, for the benefit of the state in its legislation, and of the plain people. In Pennsylvania, mining, metallurgy, manufacturing, forestry, light, heat and power, are among the living issues that require sound legislation and to prepare it should be one of the functions of the university of the state.

The United States Bureau of Education publishes annually a Bulletin of Statistics of State Universities. These include a directory of state universities and other state-aided institutions of higher education, noting specially those endowed by the federal government under the Morrill Land Grant Acts. These numbered 87, besides 16 agricultural and mechanical colleges for colored students, in the list for the year ended June 30, 1912. There are tables showing the teaching force, the student enrollment, the property and income of the 87 state universities and state-aided institutions.

State universities and state-aided institutions of higher education included in this list, corrected by figures of Professor Maphis' Report, are as follows:

		Income from Mill Tax.
Arizona	3/5 of a mill	32,000
California	22.5/100 of a mill	750,000
Colorado	3/5 of a mill	223,000
Illinois	3 mills	
Indiana	1/10 of a mill	173,000
Iowa	1/8 of a mill	
Kentucky	1/2 of a mill	47,000
Michigan	3/8 of a mill	650,000
	1/10 of a mill	173,000
Minnesota	23/100 of a mill	260,000
Nebraska	1 mill tax rate	411,000
Nevada	1/2 mill tax rate	
New Mexico	65/100 mill tax rate	
North Dakota	1/5 mill tax rate	
	33/100 mill tax rate	
Ohio	17/2000 mill tax rate	92,000
	107/2000 mill tax rate540.000	360,000
	17/2000 mill tax rate	88,000
Texas	1-3/4 p. c. gross revenue of state	
Utah	7.94 p. c. of 4-1/2 mills on the dollar	
Utah	18.04 p. c. of 4-1/2 mills on the dollar	
Wisconsin	3/8 mill tax rate	664,000
Wyoming	1/2 mill tax rate	24,000

President James of Illinois State University says the legislature of Illinois at its last session (1912) passed a law providing that a tax of one mill for every dollar of assessed valuation should be levied for the support of the university. This will give about two and a quarter million dollars per year, available July 1, 1913. Owing to the provision in the constitution of Illinois that the legislature may not make appropriations for longer than two years, the legislature must appropriate at each session the money represented by this mill tax and labeled for the support of the University of Illinois.

Michigan and Wisconsin provide for the levying of a certain so-called mill tax, three eighths or four fifths of a mill, the proceeds of which are turned over to the board of trustees of the beneficiary institution.

The statistics of state universities and other institutions of higher education partially supported by the state for the year ended June 30, 1912 (*Bulletin*, 1912, No. 33), give a great many details, among them a table of property and income of state universities and other state-aided institutions, showing that there were paid—

	By the State.	By the United States.
To the University of California	1,124,506	80,000
To the University of Indiana	1,918,900	79,938
To the University of Minnesota	2,314,713	80,000
To the University of Missouri	610,093	76,875
To the University of Nebraska	651,318	80,000
To the University of Cornell	478,000	72,000
Ohio { Ohio University, Ohio State University, Miami University }	1,131,778	50,000
To the Universty of Wisconsin	1,552,398	80,000

The same table gives the receipts from the mill tax and other sources of some of the states, as follows:

Colorado (4 institutions)	406,053
Indiana (2 institutions)	259,504
Iowa (3 institutions)	407,200
Michigan (2 institutions)	932,867
Minnesota	689,521
Nebraska	374,163
Ohio (2 institutions)	480,828
South Carolina	114,113

Utah	150,000
Wisconsin	1,103,029
Wyoming	84,000

The same table gives among the many private benefactions to those state-aided universities:

California	566,000
Nevada	150,000
Cornell	1,307,111

The records of these 87 state-aided institutions confirm the belief that private benefactions will continue to supplement in generous measure the state-aided institutions just as these show by their results that they are entitled to individual as well as state help.

Pennsylvania expended in 1912 for—

Department expenses	$ 4,972,538.34
Expense of government	5,390,798.00
Commissions	407,900.00
State institutions	3,342,348.33
Penitentiaries and reformatories	544,378.69
Semi state institutions	685,750.00
Educational	8,737,600.00
Hospitals	2,683,650.00
Homes and other charitable institutions	368,300.00
Miscellaneous	1,059,500.00
	$28,192,763.36

If the appropriations for education were made by the college and university council and those for forestry, mining, etc., by boards or commissions on which were the best experts from the universities and colleges and technical schools and museums, men of scientific attainments, the result would be economy in cost and increased efficiency.

It ought not to be difficult to fix a mill tax for higher education and to devise a plan by which it should be automatically collected and set apart and distributed by the college and university council in such a way as to do the greatest good to the greatest numbers, and at the same time invite a continuance and increase of the individual munificence so characteristic of Pennsylvania.

A bill was presented to the Legislature of Pennsylvania in March

for an automatic distribution of the aid which the state accords to hospitals and charitable institutions; if passed, it would eliminate the methods characteristic of the distribution of state funds by the legislature for purely public charities.

Another bill provides for a charities bureau in the Department of the Auditor General to carry on the duties imposed on the Auditor General and the State Board of Charities.

The purpose of these bills is to make automatic distribution of state revenue to and among hospitals and charities doing the work for the people of the state, on the basis of services rendered, and a method of full returns of receipts and expenditures, with power by inspection to correct extravagance, and to compel economy in expenses of maintenance, and to prevent unnecessary duplication of institutions, but to require of them steady improvement and constant advance in methods and results.

The growing interest and general demand for the mill tax for the support of higher education are shown in recent reports, that for Virginia by Professor Charles D. Maphis, of the University of Virginia; that for Texas by Professor Arthur Lefevre, of the University of Texas, and that for Ohio by President Alston Ellis, of Ohio University. That for Virginia is the report made by a commission to devise a systematic method to meet the demands of higher educational institutions, to prevent educational duplication and consequent financial waste, and to devise stable and systematic methods for the maintenance, management and expansion of these institutions. The report recommends for Virginia one medical school, one polytechnic school, and one university, and a permanent education commission with power to coöperate with the governing bodies of all institutions of higher education in Virginia through representatives.

Professor Maphis has collected and printed the opinions of representatives of the universities of California, Wisconsin, North Dakota, Minnesota, Kentucky, Michigan, Iowa, Illinois, and of the experts of the Carnegie Institute for the Advancement of Education, of New York, and of the Bureau of Education of Washington.

Based on these and other evidence, Virginia is advised to adopt

a mill tax for higher education and with and through it to reorganize its institutions of higher education so that they may grow with the growth of the state and with its income and make return in increased work for the state and its people.

In the college and university council of Pennsylvania the state has a capital piece of machinery for the distribution of the proceeds of a state mill tax for higher education. In that council there are the representatives of the state, the governor, the attorney general, and the superintendent of public instruction, and of the universities, Pennsylvania, Pittsburgh, Lehigh and Bucknell, and of the colleges, Washington-Jefferson, State, Franklin & Marshall, and an eminent citizen representing the Catholic institutions of higher education. With such men that council could be safely entrusted with power to make a distribution of any sum raised by a mill tax, so that it can be distributed to the greatest advantage of all the institutions of higher education in Pennsylvania.

The last report of the Superintendent of Education gives a list of six universities, twenty-nine colleges, four law schools, four dental schools, three pharmacy schools, thirteen normal schools and seven technical schools in Pennsylvania.

The state has created many examining boards for law, medicine, pharmacy, dentistry, veterinary candidates, osteopathy, accountants, and boards for the geological and topographic survey, vaccination, health, mining, etc., and all of them might well be affiliated with the college and university council, which could designate university and college experts to carry on the work.

CLIMATIC AREAS OF THE UNITED STATES AS RELATED TO PLANT GROWTH.[1]

(Plates IX, X, and XI.)

By BURTON EDWARD LIVINGSTON.

(*Read April 18, 1913.*)

Introduction.

The climatic factors which generally determine whether a given kind of plant may or may not live in a certain locality are to be divided into two groups. The first group comprises those factors which tend to increase or to decrease the moisture content of the plant body. They may be termed the moisture conditions of the environment. The second group includes the climatic factors which tend to raise or to lower the temperature of the plant. These are the temperature conditions. A third group of climatic factors includes those tending to increase or decrease the insolation of the plant and hence to promote or retard photosynthesis in green tissues, by which carbon dioxid and water are decomposed with the formation of molecular oxygen and carbohydrate. With these light conditions, however, climatic plant geography has as yet but little to do and this group will not receive attention in the discussions which follow.

Before plant geography can pass beyond its qualitatively descriptive phase, the moisture and temperature relations that obtain between plants and their surroundings must be subjected to examination much more quantitative than has heretofore been attempted. As in other similar instances, definite knowledge of this complex set of relations can be reached only through measurements of the things that are to be related. It thus appears that, for those chapters of plant geography and of scientific agriculture which have to do with climatic conditions, it will presently be found requisite to

[1] Botanical contribution from the Johns Hopkins University, No. 32.

measure both the plants dealt with and their environmental conditions. Since both plants and their surroundings are always changing, it is essential that our measurements take the form of summations or integrations. It is therefore first incumbent upon us to find means of integrating or summing the various fluctuating conditions, within and without the plant body, that determine the development of the organism and that decide whether it can exist at all in any given set of surroundings.

Measurement and summation of conditions within the plant.

Our very meager knowledge of plant dynamics would render quite hopeless, for the present, any attempt to integrate the qualities, intensities and durations of physiological processes, were it not for the fact that the plant itself furnishes at any instant a very clear and unequivocal summation of the effects of all the processes which have gone on in its body during its previous developmental history. This fact furnishes the criterion by which comparisons have usually been made between the growth processes of different kinds of living things. The amount of growth accomplished during a given time period may be determined by weighing the crop or some portion of it, a method commonly in use in agricultural studies. Another method, employed mainly by phenologists, has been to determine the length of time which may elapse during certain developmental phases of the organism. Thus may be determined the length of the time period that intervenes between seed germination or the first swelling of lead buds, and flower production or the ripening of fruits. Still more simple and more easily applied is the method which merely determines whether or not given plant forms are able to carry out their life cycles under the environmental conditions of certain localities. For the positive answer to this question mere observation frequently suffices, for its negative answer, experimentation, or at least instrumentation, is necessary. If a plant form is observed as thriving year after year and generation after generation in a certain locality, it is, as has been mentioned elsewhere, no less than redundant to point out this as an "adaptation"; but if the given form is not to be observed in this locality, the most direct and final way to

determine whether or not it can thrive there, is actually to make the experimental test.

Frequently a simple inspection of the plant dealt with, or the approximate measurement of certain of its characteristics, may suffice for an indication of its ability to withstand the water-withholding or water-extracting power of the environment. Thus, it has long been appreciated that the ability of a plant to thrive under arid conditions is often indicated by its observable physical structure. The power of an organism to withhold moisture from an arid environment seems to be closely, and usually directly, connected with structural characters which can be recognized at sight, and, on the basis of this principle, ecologists have classified plants into xerophytes, mesophytes and the like. Of course this classification must be subjected to a much more definitely quantitative treatment than the one now generally employed, that of mere observation and personal judgment, before ecology can begin to partake of the characters of an exact science. For such a resurvey of the moisture-retaining powers of plants we have now at least two practicable and fairly quantitative methods[1a] besides the directly experimental one of trying various plant forms under various climatic complexes. This is not the place to enter into a consideration of these methods, but it should be emphasized that it now appears to be possible, within a single period of twenty-four hours, to determine with considerable accuracy the position of almost any plant individual in what might be termed an absolute scale of xerophytism, as far as the water-withholding power of its aerial parts is concerned.

For the study of the effects of temperature conditions within the plant, no means is yet available excepting that of direct experiment. In one way the problem here met with is simplified by the well-known fact that plant temperatures practically always follow very closely the temperatures of the surroundings. In attempts to determine the relations between temperature and the various plant processes, it is therefore only necessary to know the effective temperature condi-

[1a] Livingston, B. E., "The Resistance Offered by Leaves to Transpirational Water Loss," *Plant World*, **16**: 1–35, 1913. Also references there given.

PROC. AMER. PHIL. SOC., LII, 209 Q. PRINTED JUNE 17, 1913.

tions of the environment and it is seldom requisite to study the temperature of the plant body separately.

The ability of a plant to withstand unfavorable temperature conditions, quite unlike its ability to withstand adverse conditions of the moisture relation, is not at all indicated by structural characteristics. It is absolutely impossible by mere observation or by any morphological study of a plant, to find a basis even for a rational guess as to the temperature conditions to which the organism may be fitted. Furthermore, no method but that of direct experimentation has been devised, and none seems likely to be forthcoming, by which plants may be studied with regard to their temperature requirements, and the appreciation and interpretation of direct experiment is here so extremely complex that scarcely any attempt has thus far been made in this direction. The result is, that, while we are well aware that temperature conditions are fully as important as those of moisture, in determining plant development and distribution, yet we are without any really quantitative knowledge of the heat relation.

Before such quantitative knowledge can be attained it will be necessary that there be made available somewhere a laboratory so equipped that all of the main conditions of plant growth may be controlled and altered at the will of the experimenter. The need of such a laboratory has been emphasized by A. de Candolle and again by Abbe,[2] who also quotes de Candolle, but, so far as I am aware, no serious attempt has ever yet been made to procure facilities for adequate experimental study of the range of conditions which various plant forms may be able to withstand. The value of such a laboratory to scientific agriculture cannot be overestimated.

For both the temperature and moisture limits of plant activities, a kind of rough and qualitative experimentation has studied the growth of the same variety of plant in different localities or of different varieties in the same locality, and has drawn volumes of vague and more or less discordant conclusions without adequate measurement either of the plants employed or of the climatic conditions to which they have been subjected. This sort of experimentation is

[2] Abbe C., First report on the relations between climates and crops. U. S. Dept. Agric. Weather Bureau Bulletin 36, 1905. See especially p. 23.

very common to-day, especially among agricultural institutions, and considerable practical information is no doubt resulting therefrom. In this agricultural work, however, as also in the observational studies upon natural vegetation, with which plant ecologists are so generally engaged, the physiological characters of plants are determined almost solely with reference to the locations at which they grow. Thus, seedsmen, to describe the physiological properties of the plants with which they deal, must name the regions in which these plants succeed. "A greatly approved variety among the truck gardeners of Long Island," "one of the most successful earlies throughout the South."—so run such trade descriptions.

Measurement and summation of environmental conditions.

When we describe the physiological capabilities of a given strain or species by stating the geographical region in which it thrives, we are of course employing the environmental conditions as a unit for measuring and defining the internal ones. Valuable as this sort of definition undoubtedly is, it falls far short of perfection, even for practical purposes. The climatic conditions of any locality vary from day to day throughout the year and their annual march is never the same for different years. An agricultural plant that proves very successful for one season in a certain place may be a complete failure for the following year. It is clear, therefore, that we must seek methods for describing climatic conditions, other than their simple reference to certain geographical regions. If such methods can be devised, even though we may have no better ways of characterizing our plants than are already at hand, it should become possible to compare the environmental conditions of different regions, and plant geography, as well as scientific agriculture, should be greatly advanced.

Methods and data.

Turning now to the consideration of the methods which are at hand for comparing climates, we are struck with an amusing fact; the most intelligible and most widely used way to do this is to characterize the climatic conditions of any region in terms of the kinds

of plants and animals which thrive there. The sage-brush is a plant with physiological characters such that it thrives best in the temperate arid regions of North America, and the climate of these regions is such as to render sage-brush the dominant and characteristic form of plant life. So we reason in a circle and arrive nowhere.

There are, however, instrumental methods more ideal, if not more satisfactory, by which climates may be compared. Thus the averages or means of temperature, precipitation, humidity, etc., of the meteorologists and climatologists, give numerical data which are, in a way, descriptive. It appears, indeed, that means or averages of the climatic data which have been and are being accumulated throughout the world should furnish a numerical basis for distinguishing between different climatic areas, and this basis has of course been employed by climatologists for many years. Ecologists and agriculturists have frequently made use of such climatic means and have so described the climates with which they have had to deal. But if you will look over any of the recent ecological papers you will find that the definition of climates has not gone very far. Usually a section of such a paper is devoted to the characterization of the climates of the areas considered, but the quantitative part of this section is little more than a mass of unrelated figures; out of these the author himself seems to make no serious attempt to draw generalizations that may be related to the corresponding vegetational areas.

We are thus confronted with a state of affairs which is far from satisfactory. The weather services of the world are expending vast amounts of wealth and energy in accumulating, year by year, observational statistics bearing upon the various climatic areas. These statistics are largely used for weather prediction and for the purposes of theoretical meteorology. It seems that quantitative climatic descriptions must lie hidden somehow in these enormous masses of figures, but the plant geographer, whether agriculturist or ecologist, has thus far been able to derive therefrom but a very small amount of applicable information.

It seems to me that the reason for this state of affairs is a double one: first, the climatological observations of our weather services

have been planned and are carried out mainly not for the study of climate as it may influence plant growth but for the study of meteorology and climatology and for weather prediction; second, the methods now employed for handling the observational data after they have been obtained are not well suited to the study of the climatic relations of plants. To make these propositions clear, we may consider the work of the United States Weather Bureau, this work being familiar to all of us and having a direct bearing upon the problems of plant distribution as I have been led to attack them. Although the Weather Bureau is officially a part of the national Department of Agriculture, being one of the largest bureaus of that department, its main activities have neven been primarily directed towards the relation between agriculture and climatology. Weather prediction and weather history seem to have been almost the sole scientific aims of the organization up to the present time. The student of plant activities will find no fault with these aims, but he may wonder how it has come about that an agricultural bureau has so thoroughly ignored what we must regard as by far the most important relation which exists between human welfare and climate; that is, the relation between plant growth and the climatic features of plant surroundings.

As to the making of climatic observations, it is clear that observatories in the rural districts are the only ones whose records are properly available for our present purposes. It is a curious fact which speaks for the political or commercial rather than scientific nature of our Bureau's organization, that the best equipped observatories in this country are generally located in large cities, and usually high in the air. As the population of the United States has increased you may note a somewhat parallel increase in the average distance of the climatic observatories from the ground. This of course ought not to be. If political and commercial interests demand observatories in the urban districts the records from these should be treated only as special studies of special conditions. It is interesting to note that the charts of Day's[3] recent bulletin upon frost data have

[3] Day, P. C., "Frost Data of the United States," etc., U. S. Dept. Agric: Weather Bureau Bulletin V, 1911.

been compiled, as the author states, wholly from the observations of rural stations. The requisite stations must be, however, in the open country, and not even in small towns.

Furthermore, the geographical distribution of Weather Bureau stations in the United States is anything but rational. Being located mainly in large cities, these stations cluster thickly east of the Mississippi River and are widely separated in the western half of the country. Such an arrangement has, no doubt, its political, commercial, financial and historical reasons; nevertheless, it is scientifically quite the opposite of rational, for climatic gradients are gentle in the east and very abrupt in the west.

For the purposes of the student of vegetational-climatic relations, the actual observations might be greatly improved. As far as the temperature conditions are concerned, the observational methods are fairly well worked out for the present. In the future we shall need a thermo-integrator, the indications of which may bear some at least empirical relation to plant growth, but such instruments remain to be devised. As has been pointed out, the moisture conditions of the environment affect the activities of a plant through their influence toward increasing or decreasing its water content. Now, most plants—and *all* agricultural plants—derive water mainly from the soil and lose it mainly to the air. It is thus clear that, with proper consideration of soil conditions, the data of precipitation should furnish us with a valuable criterion for comparing climatic areas. Precipitation is easily measured and our information in this connection is fairly satisfactory. For the other factor of the moisture relation of plants, however, namely the power of the aerial surroundings to extract water from the plant, the climatic data which have been accumulated in this country furnish practically no information. The available measurements and averages bearing on this point are those of relative humidity (a somewhat artificial abstraction), pressure of water vapor, wind velocity, temperature and sunshine intensity. While the present method of measuring rainfall is self-integrating and leaves little to be desired in the way of improvement, the methods employed in measuring the water-extracting factors just mentioned all involve artificial manipulations before any

climatic characteristics can be derived therefrom. Indeed, the sunshine data furnished by the weather observatories is not even quantitative in any adequate sense.

In the face of these difficulties ecology has been forced to turn entirely away from the available meteorological data. It is apparent at once that the water-extracting power of the aerial environment is effective through the evaporating power of the air and the intensity of sunlight. The sunlight factor appears frequently to be of comparatively little importance in the climatic moisture relation, though its effects in removing water from moist objects such as plants can now be measured and automatically integrated with considerable readiness.[4] The evaporating power of the air (a complex of the effects of vapor pressure and wind movement) appears, on the other hand, to be generally of prime importance. This fact has long been recognized and meteorologists outside of the United States have accumulated a vast amount of information upon evaporation as a climatic factor.[5] Meeting with difficulties in the standardization of atmometers, many workers have turned their attention to attempts to derive a formula by which evaporation might be computed from the meteorological factors usually measured. An enormous amount of work has been done in this line, but the results are of little value for climatological purposes. At the same time various students of climatology and of plant activities have devised numerous forms of atmometers, for measuring and automatically integrating the evaporating power of the air directly. Since the latter is a very complex factor, it comes about that data from different kinds of instruments cannot be readily reduced to a common standard, so that there has been some hesitation in making evaporation measurements a general feature of climatological work. It is nevertheless true that, for our present purposes at least, all that is required is that some one form

[4] Livingston, B. E., "A Radio-atmometer for Measuring Light Intensities," *Plant World*, 14: 96–99, 1911; "Light Intensity and Transpiration," *Bot. Gaz.*, 52: 418–438, 1911.

[5] In this connection see Livingston, Grace J., "An Annotated Bibliography of Evaporation," *Mo. Weather Rev.*, 36: 181–6, 301–6, 375–81, 1908; 37: 68–72, 103–9, 157–60, 193–9, 248–52, 1909. Also reprinted and repaged 1–121, 1909. The subject has very recently attracted much more attention than formerly, especially from agriculturalists and ecologists.

of atmometer be generally adopted, and many weather services are at present furnishing data upon evaporation as well as upon the other climatic factors more commonly recorded. On account of various difficulties arising from the use of a free water surface for measuring evaporation, the most valuable instruments now available determine the evaporation rates from the surface of an imbibed solid, such as bibulous paper or porous porcelain. For plant ecology the porous cup atmometer[6] appears to be the most satisfactory of these instruments, and it seems to be rapidly rising in the esteem of agriculturists and others who are interested in this line of study. This instrument has the advantage, for our purpose, that its evaporating surface is so exposed as to be fairly comparable to the evaporating surfaces of plants.

The only systematic information which the United States Weather Bureau has furnished upon the geographical distribution of evaporation intensities is comprised in the report of Russell's[7] studies. This author employed Piche atmometers at nineteen stations and derived a formula from the results thus obtained, by which the monthly evaporation rates for many other stations were derived. His operations extended over a single year, from July, 1887, to June, 1888, and a very valuable chart of evaporation in the United States resulted therefrom.

During the summers of 1907 and 1908 I carried out a comparative study of evaporation intensities throughout the United States, under the auspices of the Department of Botanical Research of the Carnegie Institution, using the standardized porous cup atmometer.

[6] On the porous clay atmometer, see:

Babinet, J., "Note sur un atmidoscope," *Compt. Rend.*, **27**: 529–30, 1848. Marié-Davy, H., "Atmidomètre à vase poreaux de Babinet," *Nouv. Met.*, **2**: 253–4, 1869; Mitscherlich, Alfred, "Ein Verdunstungsmesser," *Landw. Versuchsstat.*, **60**: 63–72, 1904; also **61**: 320, 1904; Livingston, B. E., "The Relation of Desert Plants to Soil Moisture and to Evaporation," Carnegie Inst. Wash. Publ. 50, Washington, 1906; "A Simple Atmometer," *Science*, N. S., **28**: 319–20, 1908; "A Rotating Table for Standardizing Porous Cup Atmometers," *Plant World*, **15**: 157–62, 1912; also other literature there referred to.

[7] Russell, Thomas, "Depth of Evaporation in the United States," *Mo. Weather Rev.*, **16**: 235–9, 1888.

The results of these studies have been published[8] and furnish, for fifteen weeks only, the second chart of evaporation which has ever been prepared for this country. It is interesting to note that a fifth of a century elapsed between these two studies, and that nothing further has yet been attempted.

Judging from the results already obtained, it appears that the simple measurement and automatic summation of the evaporating power of the air for the various climatic areas furnishes as satisfactory a measure of the water-extracting power of the environment as the student of plant relations can hope for from a single condition, and the future development of this branch of science will depend largely upon whether or not comparative evaporation records may become available.

Treatment of observational data.

The frostless season.—In the preceding paragraphs have been considered the most requisite methods for obtaining climatic observations. We shall now turn our attention to the application of these observations after they have been obtained. It is the custom of meteorologists to derive from the actual observations, daily means, monthly means and annual means, and to give most attention to the latter. Now, for the purposes of vegetational-climatic investigations, it appears that none of these means offers much assistance. In the determination of plant activities, at least in the majority of cases, the controlling climatic factors are primarily effective only during the growing season, and I am convinced that this season should form the basis of a large part of the manipulation of climatic records, which which we are here interested. As an approximation of the vegetational growing season, for general use throughout our country, it seems most promising to adopt the length of the frostless season, the number of days intervening between the average dates of the last killing frost in spring and the first in autumn. That other duration factors will be required in many cases is not to be doubted,

[8] Livingston, B. E., "A Study of the Relation between Summer Evaporation Intensity and Centers of Plant Distribution in the United States," *Plant World*, **14**: 205–22, 1911.

but this appears to be far more broadly applicable than any other. The actual data of mean length of the frostless season in the United States have never been published, but Day's chart (already referred to) presents a general view of the range in length of this period which this country affords. Data corresponding to those from which Day's chart of the frostless season was compiled have been deduced from the average dates of last and first killing frosts as given in the 106 Sumaries by Sections[9] published by the Weather Bureau. These deduced data have been used in deriving the other climatic indices considered below.

Temperature integration.—The mean length of the frostless season is of course primarily a temperature condition, but it tells us nothing of the normal temperatures which may prevail within the period designated, only that killing frosts do not normally occur. In order to be able to relate the temperatures of the frostless season to plant activities it is thus obvious that we shall need to sum or integrate the temperatures over the period of active growth. As has been said, the mature plant itself is to be regarded as a summation of all of the accelerations and retardations which have occurred during its life, so that our integration of temperatures should attempt to consider these, not merely as they affect our thermometers, but rather *as they affect plants.* This is, however, practically impossible until we have at our disposal a much larger fund of information concerning the general relation of plant activities to temperature, and such information is not apt to be forthcoming until such time as the laboratory for controlled conditions, mentioned above, may become a fact instead of a mere dream. Various procedures of temperature integration have been devised by different writers and appear to be more or less valuable in this connection, but the physiological basis for such procedures remains still to be established. Under the circumstances, it seems best here to give attention to but a single one. This is the method of direct summation of the daily normal means throughout the period in question.

[9] "Summary of the Climatological Data of the United States, by Sections," U. S. Department of Agriculture Weather Bureau. No date. The 106 pamphlets appear to have been prepared about 1909–10. The data extend for the most part through 1908 or 1909.

Bigelow[10] has given us the daily normal temperatures throughout the year for 177 stations well distributed over the country. This excellent piece of work has laid the foundation for many kinds of climatological study that would otherwise be impossible. The data are generally based on an observation period of about thirty years and may be regarded as quite as reliable as any other data that we now have. In summing the daily normal temepratures for the days within the average frostless season, for each one of the numerous stations, some temperature must be assumed as a starting point. I have taken 32° F. The results of such summations may be termed average or normal temperature summations, above 32° F., for the frostless season at the various stations.

The method here used is somewhat similar to that employed by Merriam[11] in his well-known study of the temperature relation in the United States. This author did not use the average length of the frostless season, however, and his manipulations differed from my own in other details. The general method of summations is not at all new, having been long employed by phenologists.

When we plot the temperature summation indices upon a map and draw isoclimatic lines in the usual way, there results a chart which presents the country divided into zones or bands. Such a chart is shown by the dotted lines of plates IX., X., and XI. Without entering into details, it is at once seen that the temperature summation zones cross the continent in a generally west-east direction, being southwardly displaced in the regions of the two mountain systems and also to some extent along the Pacific seaboard. Practically all of the area of the United States is characterized, according to this chart, by normal temperature summation indices ranging from 3,000 to 13,000. The southern half of the Florida peninsula exhibits still higher indices.

Integrations of the moisture relation. 1. General considerations.—While temperature furnishes us a single means of studying

[10] Bigelow, F. H., "The Daily Normal Temperature and Daily Normal Precipitation of the United States," U. S. Dept. Agric. Weather Bureau Bulletin R, 1908.

[11] Merriam, C. H., "Laws of Temperature Control of the Geographic Distribution of Animals and Plants," *Nat. Geog. Mag.*, **6**: 229–38, 1894.

both the tendency of the plant to gain heat and its tendency to lose heat, we find no such simple climatic factor to use in studying the conditions which tend to add water to the plant or to remove it. As has previously been mentioned, the ordinary plant derives most of its moisture supply from the soil and loses water to the air. The possible rate of moisture supply to growing plants is thus determined by the resistance of the soil to the movement of moisture into plant roots. While the physical properties of the soil play an important part in this connection and while these vary from place to place, the amount of water present in the soil is also of primary importance. This depends, for any particular soil and in the majority of cases, upon precipitation, and the measurement of this climatic factor furnishes us, as is commonly recognized, with a criterion of considerable value in the comparison of climatic areas. While the distribution of rainfall throughout the period of the plant's activities is fully as important as its amount, I shall give attention in this paper only to the latter.

It has already been emphasized that the evaporating power of the air is the main climatic feature in the control of water loss from plants, as from other moist objects. If we add to this the water-extracting or desiccating power of the sunshine we have an exceedingly satisfactory measure of the water requirements of plants, for most of the water absorbed by ordinary plants is lost by transpiration. Here also I shall consider only the question of the mean evaporating power of the air throughout the period of the frostless season.

If we assume for the moment that soils are all alike in their physical properties, and if the moisture supply of plants be proportional to precipitation while the water loss is proportional to the evaporating power of the air, some relation obtaining between these two factors should be a direct measure of the vegetational water relation. Unfortunately for our study, the assumptions above made, especially the one regarding the physical properties of soils, are very far from true; yet certain physical types of soil are found in every one of the climatic areas which we are apt to encounter, and for any such type the relation just referred to should be of great value.

Thus, heavy clays occur commonly throughout the United States and the moisture relation of plants growing thereon may be approximately proportional to the relation of precipitation to evaporation. A similar proposition may hold for sandy soils. It is, however, to be noted that a sandy soil and a clay soil under the same climatic conditions ought not to be expected to possess the same power of supplying moisture to plants.

The relation of precipitation to evaporation was first emphasized as a climatic factor influencing vegetational distribution in the United States by Transeau,[12] who constructed a very interesting and valuable chart of the eastern portion of our country on the basis of the ratio of mean annual precipitation to the annual evaporation obtained by Russell for a single year. Another, and in some ways more satisfactory relation between rainfall and evaporation is the *difference* between these factors, precipitation *minus* evaporation. I have tested this as extensively as our extremely meager data on evaporation will allow. In the present paper attention will be confined to this index of difference for the frostless season.

We now turn our attention to three examples of the quantitative study of the moisture relations of the United States, resulting in the means of precipitation, of evaporation and of the difference between these two for the frostless season.

2. Amount of precipitation during the frostless season.—Bigelow has given us, by means of very ingenious and elaborate methods, a table showing the daily normal precipitation for each of 177 stations in the United States, and it is upon this valuable work that I have based all of my quantitative studies of rainfall. In the present instance, wherein the normal distribution of precipitation during the year will receive no attention, I have merely determined the average normal daily precipitation at each station throughout the frostless season. This gives a precipitation index which is at once seen to be definitely related to plant activities. Stations with high precipitation indices are situated in the humid regions, those with low indices are in the arid regions.

[12] Transeau, E. N., "Forests of Eastern America," *Amer. Nat.*, 39: 875–98, 1905; "Climatic Centers and Centers of Plant Distribution," Mich. Acad. Sci. 7th Ann. Rept., 1905.

When these indices are placed upon a map and isoclimatic lines are drawn in the usual way, we have the chart which is shown in full lines in plate IX.[13] The data are in terms of hundredths of an inch per day and their range of magnitude is from less than two to over sixteen hundredths. This is not a proper place for detailed discussion, but it is at once obvious that the precipitation lines of this chart tend strongly to take a north-south direction, thus crossing our isothermal lines and dividing the country into irregular climatic areas each of which might be defined by the use of these two systems of lines. As has been stated, the data from which both temperature and precipitation charts have been constructed are relatively very satisfactory, and it may be surmised that the combination chart here presented is fairly reliable as a general picture of the climatic conditions of the country as measured according to the method here set forth.

3. Amount of evaporation during the frostless season.—Russell's data on evaporation in the United States are for but a single year, and that not a calendar one. The probability of error introduced by assuming these data to be normal is very great, yet, as has been emphasized, these are the only data yet available, and we must either employ them or follow the custom of our Weather Bureau and ignore the important subject of direct evaporation measurements entirely. More to illustrate the value of evaporation records than with any thought that the details of the present study may be free from large error, I present here the results of an approximate determination of the mean depth of daily evaporation for the frostless season. It is to be noted that the data for the earlier months of the frostless season are from the summer of 1888, while those for the later months are from that of 1887, an unsatisfactory state of affairs made necessary by the exigencies of Russell's study.

Russell's published data are given by months, and, since the

[13] It is to be remarked that this and the two following charts attempt no more than an approximation to normal conditions. The lines are so placed, however, as to represent the data as these have been obtained. Where no stations are present topography has been used as an indication of the probable position of the lines. All of the data here employed will be published elsewhere.

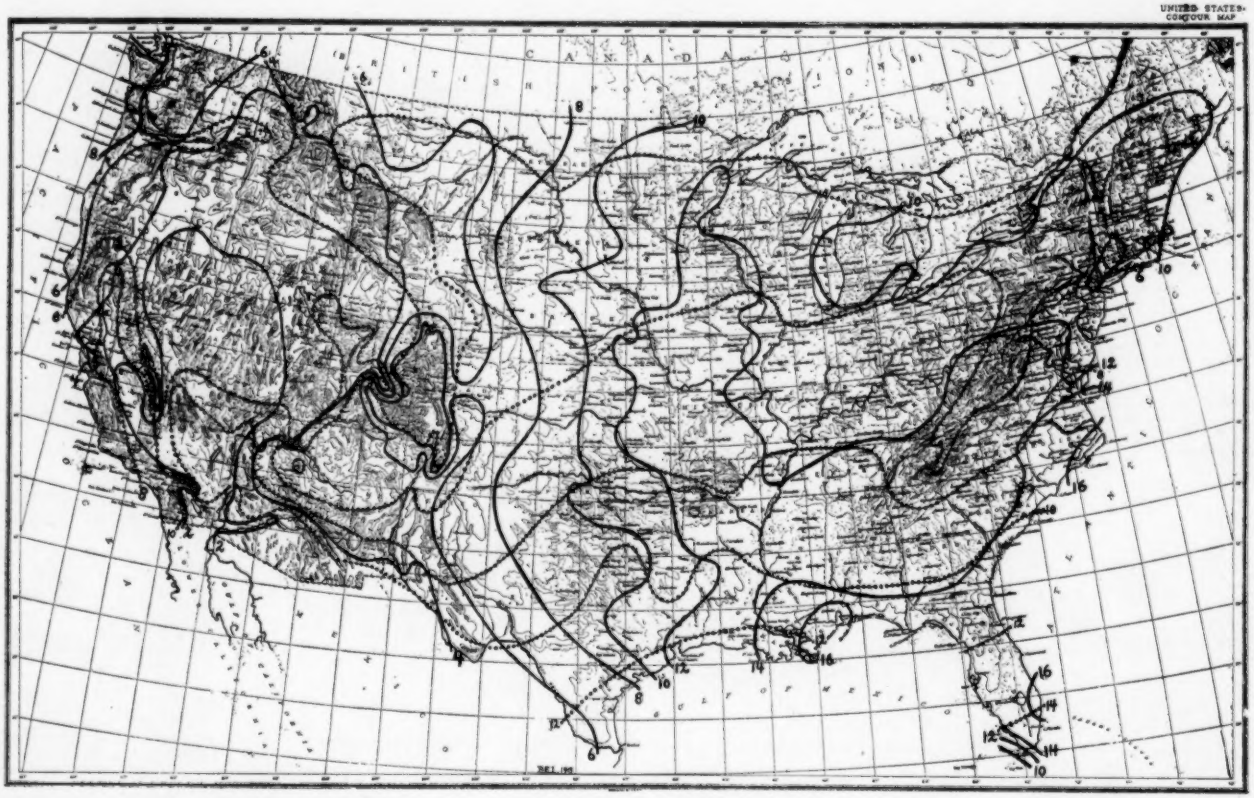

PLATE IX. Chart showing climatic mosaic formed by two systems of isoclimatic lines. Broken lines represent temperature summation indices (in thousands) and full lines show precipitation indices (in hundredths of an inch per day) for the mean frostless season.

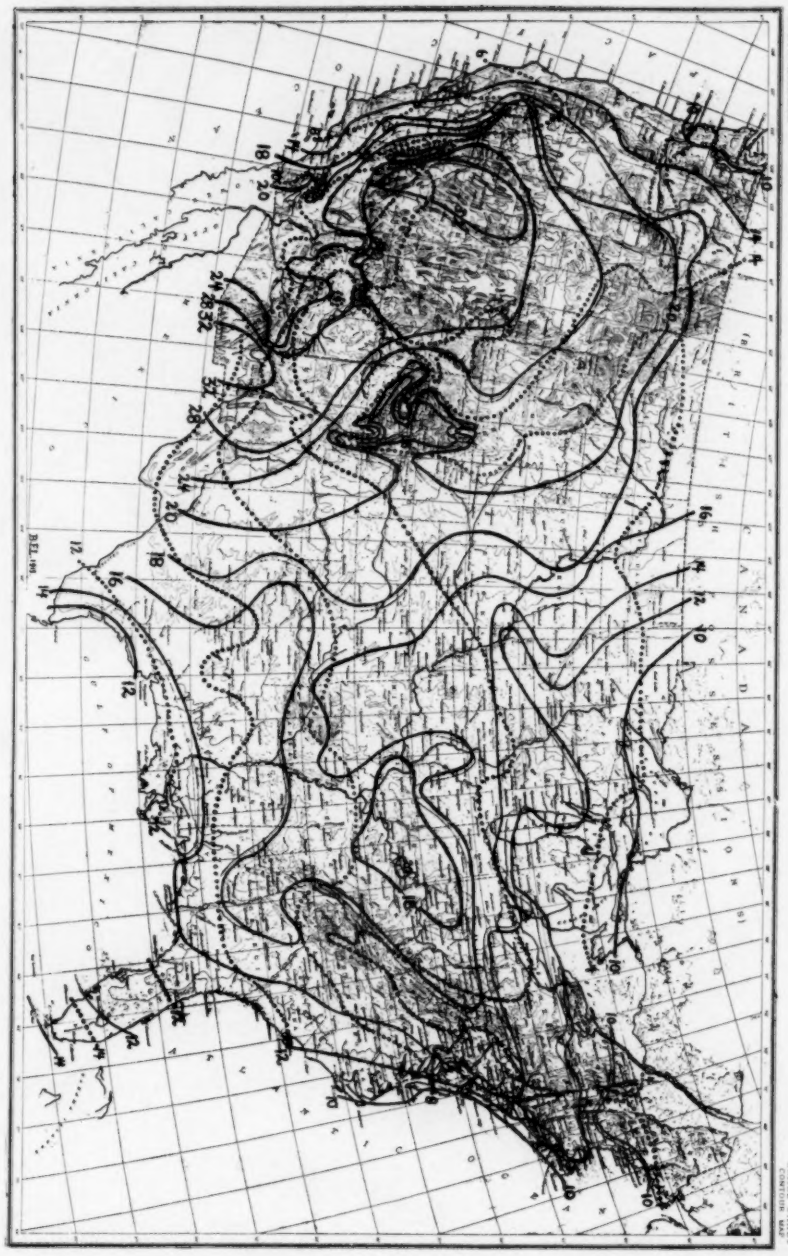

PLATE X. Chart showing climatic mosaic, as in plate IX, but the isoclimatic lines of temperature (broken) are here combined with a system of lines (full) representing evaporation indices (in hundredths of an inch per day) for the mean frostless season.

PROC. AMER. PHILOS. SOC. LII, 209 R. PRINTED JUNE 18, 1913.

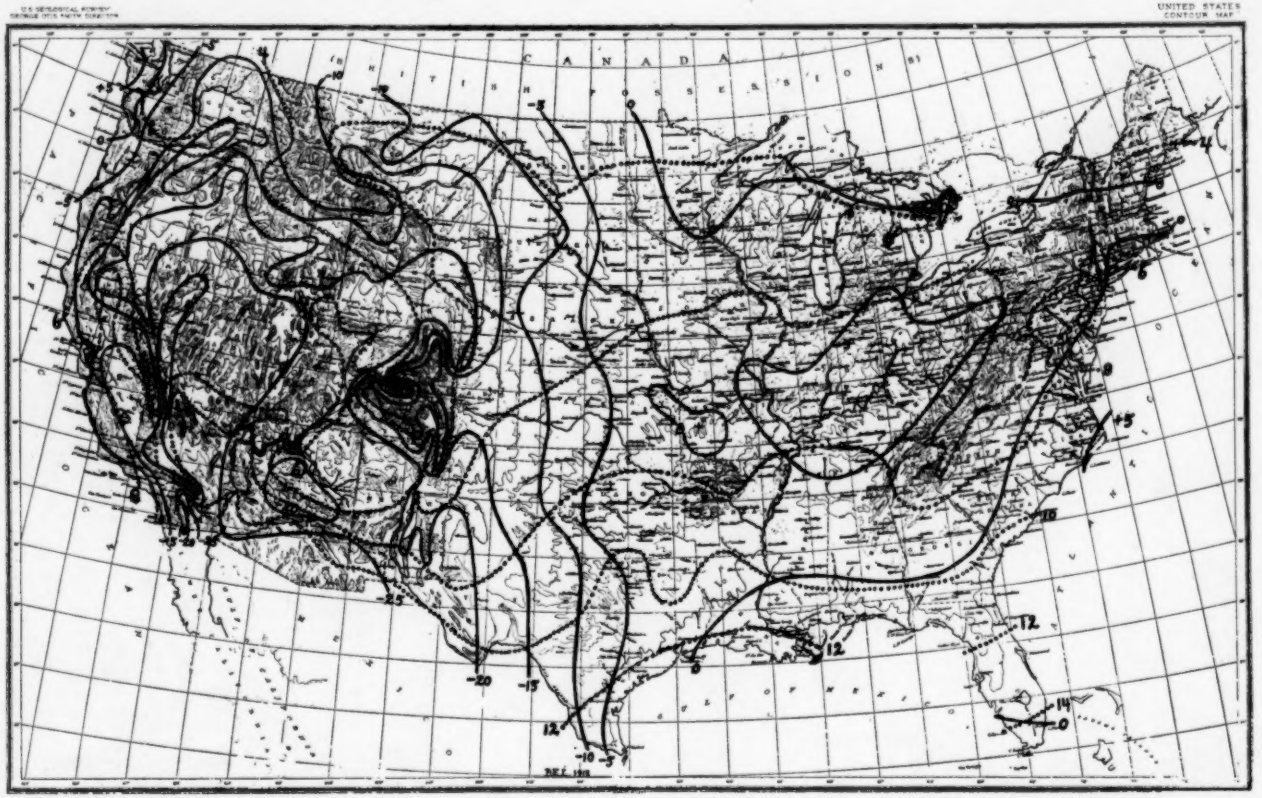

PLATE XI. Chart showing climatic mosaic, as in plates IX and X, but the isoclimatic lines of temperature (broken) are here combined with a system of lines (full) representing the differences between precipitation and evaporation indices (in hundredths of an inch per day) for the mean frostless season. Stations having two indices equal are on the zero lines. Plus areas have higher precipitation than evaporation indices, minus ones have lower.

normal frostless season rarely begins or ends with a month, it has been generally necessary to interpolate values for fractions of a month at the beginning and end of each season. The evaporation indices obtained are in terms of mean daily loss in depth from a small pan of water, in hundredths of an inch. When these indices of daily evaporation are plotted on the map and the isoatmic lines are drawn, there results the chart which appears in full lines in plate X. Here, as in the case of the precipitation chart, we observe a marked tendency of the lines to take a north-south trend and thus to cut the temperature lines so as to make of the country a climatic mosaic somewhat similar to that presented by the preceding chart. The range of daily evaporation appears here to be from less than ten to more than thirty-two hundredths of an inch.

4. Moisture excess or deficit during the frostless season.—Determining, for each station considered, the difference between the indices of precipitation and of evaporation, it is found that these differences are approximately zero for some stations and are either positive or negative for others. If the differences thus obtained are placed upon a map it is possible to draw isoclimatic lines again dividing the country into areas (full lines, plate XI.). As has been mentioned, these areas or zones may be tentatively taken to be characterized by the conditions of the plant water relation. The data are again in terms of hundredths of an inch per day, during the frostless season. They range from a negative value of 30 to a positive one of more than 5. Almost the entire country is seen to have a moisture deficit (*i. e.*, evaporation is greater than precipitation, as here measured). Only the extreme northwest, a small area in Missouri, and a narrow zone near the eastern half of our northern boundary, continued southward along the Atlantic seaboard and westward along the margin of the Gulf of Mexico as far as Texas, exhibit a moisture excess. Of course the highest deficits occur in the most arid areas. These lines of moisture excess or deficit are seen also generally to possess a north-south trend. Here again the country is subdivided into areas by the crossing of temperature and moisture lines and the various areas are susceptible of definition by means of these lines. The unsatisfactory condition of the evapora-

tion data upon which the present study has necessarily been based renders this chart of doubtful accuracy as a picture of normal conditions, but it serves its purpose admirably, of illustrating something of what may be possible in the way of quantitative vegetational climatology, whenever the attention of climatologists may be seriously attracted to this aspect of the application of their science.

The relation of vegetation to climate.

In order to study vegetational distribution as this is related to such climatic areas as have been brought out on the charts here presented, it is of course necessary to have recourse to corresponding charts showing the distribution of natural or cultivated plants. It would be beyond the scope of the present paper to attempt to show by examples how the area occupied by any plant may thus be climatically characterized, and such examples will not be brought forward here. It may be repeated, however, that the obvious and visible characters of the great vegetational types (such as those of conifer and deciduous forest, grassland and desert), while exhibiting an unequivocal relation to moisture conditions, still bear no relation to conditions of temperature. Only when the thus far practically insensible physiological characters of plants may be considered will it become possible to relate their distribution to temperature conditions.

The student of the climatic relations of plants must bear in mind the extremely complex nature of the conditional complex which must determine plant distribution. Aside from climatic conditions, the nature of the soil usually plays an important part, as has been emphasized. Furthermore, numerous mechanical and other factors may have determined, in the past, whether or not a given plant form may ever have reached a specified locality. Because of this historic factor in plant geography, the climatic and soil conditions cannot be taken as limiting distribution unless we are certain that the plants thus limited have been tried throughout the region under discussion. After they have been tried the historic factor vanishes from our consideration. Nevertheless, without recourse to this removal of the historic factor from the argument, it is still quite possible and logic-

ally sound to study the relations which obtain between vegetational areas and climatic areas. This sort of relation is truly only a spatial one, however, and must not be assumed to be causal. The probability that such a relation is a causal one is of course increased as it is found to hold in a large number of cases. With agricultural plants the historic factor need not be considered; the actual experimental test as to whether a given form will thrive in a given area is somewhat readily made and the results are clear enough.

JOHNS HOPKINS UNIVERSITY,
April 18, 1913.

SOME DIFFRACTION PHENOMENA; SUPERPOSED FRINGES.[1]

By CHARLES F. BRUSH.

(*Read April 19, 1913.*)

Fresnel observed that diffraction fringes, outside the shadow, are not affected by the thickness or shape of the diffracting edge so long as the latter is smooth and straight; and cited, as an instance, the back and edge of a razor, which gave identical fringes under the conditions of his experiment. Presumably he observed the fringes as developed several decimeters, or even meters, from the diffracting edge in the usual way.

I have found, however, that when the fringes are observed within a millimeter or two of the diffracting edge, by means of a microscope, they are very greatly influenced in brightness and sharpness by the contour of the edge.

In most of my experiments I have used cylindrical edges in order that their shape and curvature might be accurately known. I have used fine wires grading up from 0.02 of a millimeter in diameter to fine needles, thence to medium and large needles, and small, medium and large brass rods and tubes, always with a smooth surface. The fine wires and needles were screened on one side to confine diffraction to the other side only.

In the diagram of my apparatus *A* represents the source of light, which conveniently may be a short section of a tungsten lamp filament; *B* is a spectrometer slit parallel with the lamp filament and very nearly closed. *C* is the diffracting screen located 15 or 20 cm. from the slit, with its edge adjusted parallel with the slit by turning the stage of the microscope *D*. *D* is a microscope provided with a 5.0 or 2.5 cm. objective and a strong eyepiece giving a magnifying

[1] Presented in preliminary form before The American Asociation for the Advancement of Science, December 30, 1912.

power of 100 to 200 diameters. The focal plane of the objective is usually adjusted near the diffracting edge as indicated by the dotted line, and it must be borne in mind that this is where the fringes are seen.

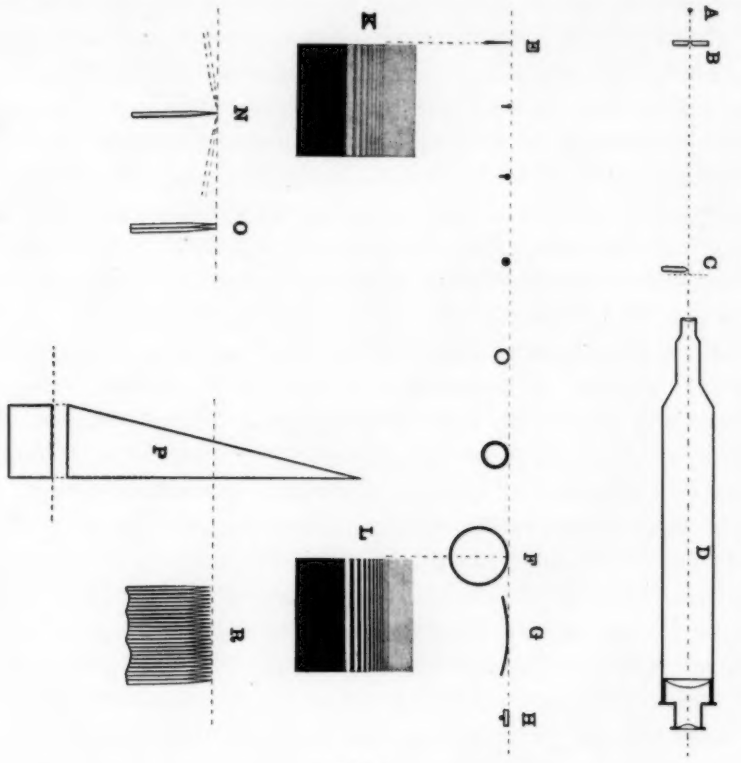

FIG. 1.

From *E* to *F* a series of cylindrical edges of progressively increasing radii is indicated. *E*, however, is a sharp razor blade, and the fringes projected by its edge are shown, greatly magnified, at *K*. They are weak, few in number and hazy in outline; but these conditions are not due to any irregularity of the edge. When a fine wire is used the fringes are distinctly better. Every time the radius of the cylindrical edge is doubled, the fringes are unmistakably brighter and sharper. *L* indicates the fringes produced by the cylin-

der *F*, of 22 mm. radius. They are very bright and sharp, and nearly free from color. From 12 to 15 may be seen. The curved plate *G*, of many cm. radius, gives fringes perceptibly brighter than *F*.

When the radius of the cylindrical edge is rather less than one millimeter, all fringes disappear if the focal plane is advanced sufficiently to coincide with the median plane of the edge, as would be expected. But when the radius is a millimeter or more, sharp, narrow fringes may be seen with the focal plane in this position, and these fringes grow broader and more numerous as the radius of the diffracting edge is increased. Evidently they are formed by elements of the cylindrical edge lying beyond (toward the light) the element in the median plane. If, now, the focal plane of the microscope is slowly advanced toward the light, these fringes slowly retreat behind the edge without greatly changing their spacing. They remain visible for some distance behind the edge because the angular aperture of the microscope objective enables the observer to see around and beyond the edge to some extent. Upon reversing the movement of the focal plane the fringes move laterally from behind the edge until the median plane is reached, when the lateral movement stops abruptly and the fringe pattern simply broadens out as the retreat of the focal plane continues.

I am led to the belief that the very greatly enhanced brightness of the fringes produced by the diffracting edge of large radius as compared with the razor edge, is due to the superposition of a number of diffraction fringe patterns which are almost, but not quite, in register. This view is supported by experiments illustrated in diagrams *N* and *O*.

N shows a razor blade greatly enlarged. It makes not the slightest difference in the fringes whether the blade is in the full line position shown, or in either of the dotted line positions, the essential condition being that the light undergoing diffraction shall not strike the beveled side of the blade.

At *O* two razor blades are shown clamped together with their edges as close as possible (about 0.2 mm.), and as nearly as possible in the same plane. The combination is adapted to be rotated slightly about the line of one of the edges as an axis by means of a tangent

screw, so that the edge nearer the light may be withdrawn very slightly below the plane of the incident beam which strikes the other edge. When this adjustment is just right the brightness of the one-blade fringes is approximately doubled, clearly indicating that two superposed fringe-patterns are formed. It appears that twice as many elements of each wave front are affected.

We may regard the cylindrical diffracting surfaces as consisting of a great many parallel elements, each acting as a diffracting edge and producing its own fringe pattern which is superposed on those of the other elements. This superposition of fringes is not apparent when they are viewed in the usual way, *i. e.*, in a plane far removed from the diffracting edge, because nearly all of the patterns have their origins so far behind (toward the light) the tangent element of the edge that they are hidden by it. The method of viewing the fringes herein described, however, enables the observer to see these hidden fringe patterns, as already pointed out.

Measurements, the details of which need not be gone into, show that in the case of the cylinder *F*, of 22 mm. radius, the width of the strip of surface involved in producing the best and brightest fringe pattern is about 1.5 mm., though 0.9 mm. gives all but the extreme lines. Smoking the surface of the cylinder makes very little difference in the brightness of the fringes, and the slight loss observed is accounted for by the roughening of the surface.

Careful eyepiece micrometer measurements of the spacing of the fringes formed by the razor edge *E*, and a cylinder of small radius agree perfectly with the theoretical spacing of diffraction fringes. But with the large cylinder *F* (and still more so with the curved surface *G*) the spaces diminish less rapidly toward the outer margin of the pattern and the outer fringes lose their sharpness, because the many superposed fringe patterns which form the composite pattern observed are not quite in register; so that beyond 12 or 15 fringes many maxima and minima so far coincide that no more lines are seen.

The reason why the numerous patterns are not perfectly in register becomes clear when we consider that they have their origins at different distances from the focal plane of the microscope, and

hence are seen spread to different extents. This discrepancy is partially offset by the lateral displacements of the origins due to the curvature of the diffracting surface, and the net result is that the composite pattern seen is brightest and sharpest in a few fringes only, the position of which may be shifted to some extent by shifting the focal plane.

Diagram *H* shows the end of a glass plate with optically plane polished upper surface 12 mm. wide, bounded by straight edges. It may be regarded as a portion of a cylinder of infinite radius, constituting one end of a series of curved diffracting surfaces of which the razor edge *E* is the other limit. The plate is adapted to be slightly rocked by tangent-screw mechanism so that its face may be adjusted very nearly parallel with the incident light.

When thus adjusted Lloyd's so-called "single-mirror interference fringes" are brilliantly shown, and the focal plane of the microscope may be moved through a wide range over the face of the mirror without disturbing the fringes in any way, proving that they have their origin on the surface of the mirror or plate, and not at its edges. The first one or two dark bands are very black and sharp, and the others show more and more color, until the fifth and beyond are all color. Only seven or eight fringes can be seen, and their spacing is sensibly uniform, as with ordinary interference fringes.

I shall now endeavor to show that these so-called "single-mirror interference fringes" are not due to interference of light reflected at grazing incidence with contiguous rays not reflected, as commonly supposed, but are superposed diffraction fringes like those already described.

Considered from this point of view, the origins of the many superposed fringe patterns all lie in the same plane and very nearly in the line of sight, and hence, owing to unequal spreading of the several patterns as already explained, some maxima begin to overlap some minima not far from the major edge of the composite pattern. Therefore few fringes are seen, and most of them are colored.

The extreme blackness of the dark bands forcibly suggests superposition of many minima. If the very small angle between the face of the mirror and the incident beam of light is gradually increased

by slowly turning the tangent screw, the fringes move closer together and lose their uniform spacing and most of their color, while the sharpest and blackest bands move further out in the pattern.

The width of the mirror, in the line of sight, may be reduced to 2 mm. without affecting the fringes in any respect; but with continued further reduction the fringes progressively lose their color, increase in number, and assume the characteristic spacing of diffraction fringes strongly reinforced by superposition of patterns, when the width is only a fraction of a millimeter.

These phenomena are beautifully shown by means of the device illustrated in diagram *P*. The plane glass mirror is here shown both in plan and elevation and enlarged to the scale of the razor blades *N* and *R*. It is in the form of a thin wedge about 12 mm. long and 3 mm. wide at the base, giving a triangular face. The line of sight is indicated by the dotted line.

Having adjusted the face of the mirror so as to produce the Lloyd fringes, and with the near edge of the mirror in the focal plane so as to prevent any edge effect, the mirror is very slowly moved on the microscope stage across the line of sight toward the point, without change of angle with the incident light. During this movement all the last described effects are developed. I may add that smoking the face of mirror *H* or *P* does not materially affect the brilliancy of the fringes.

In view of the facts cited it seems clear that the so-called "single-mirror interference fringes" of Lloyd are superposed diffraction fringes, and are not due to reflection. But to remove all doubt the device shown in diagram *R* was constructed.

This consists of 24 paper-thin razor blades clamped together and forming a bundle about 4 mm. thick. It is essential that all the edges be accurately brought to the same plane. But inasmuch as the edges of the blades are not perfectly straight, this condition can be realized only in two lines across the edge of the bundle. To effect this adjustment, the edges of the blades, very loosely clamped together, were allowed to rest by gravity against two parallel straight glass rods about half the length of the blades apart, and then cautiously clamped tight. Great care was taken to avoid injury to the

edges where they touched the rods, because it is only in these lines of contact, or very near them, that the effects to be described are produced. The glass rods were then removed and the bundle of blades was mounted and used in the same manner as the two-blade system *O* already described.

With this device, which precludes reflection, all the effects described in connection with the mirror *H* may be reproduced, differing only, and differing but little, in brilliancy. As only about half of all the edges (2 mm. across the edge of the bundle) are effective at any one time in producing visible fringes, it seems remarkable that the latter are so brilliant. But we must bear in mind that, say, twelve superposed fringe patterns will concentrate nearly all the light into the bright bands, leaving the dark bands nearly black; so that the contrasts should be nearly as strong as those produced by the far greater number of superposed patterns given by the mirror *H*.

The device *R* shows also something more of interest. Owing to the limited number of patterns formed, failure in registry may be seen at some points as division of a normal black band into two narrower dark lines which merge when the tangent screw is slightly turned, or the focal plane slightly moved; and this phenomenon may be shifted to different parts of the composite pattern by continuing either or both of these adjustments. Thus relative shifting of various fringe patterns, each more or less reinforced, is made obvious.

MATTER IN ITS ELECTRICALLY EXPLOSIVE STATE.

By FRANCIS E. NIPHER.

(*Read April 19, 1913.*)

In 1815 Singer published in the *Philosophical Magazine*[1] an account of experiments made in Holland by De Nelis, and repeated by him, which illustrated what he called the explosive effects of electricity. At that time the one-fluid theory was generally held by those familiar with electrical phenomena. It was, however, their belief that the electrical discharge came from the positive terminal.

Singer made use of a battery of jars having an external tin-foil area of 75 square feet. The positive terminal of this battery was separated from a terminal leading to a wire of lead having a diameter of 0.01 inch. This lead wire was within a small metal cylinder formed by boring a hole into a metal rod. One end of the wire was in contact with the bottom of the bore, the other being attached to a copper wire through which the discharge was sent to the lead wire. This leading in wire was surrounded by wax, and the lead wire was surrounded by oil. The lead wire was exploded by each discharge. The metal cylinder was stronger than any gun-barrel. It, however, was shattered by the explosive effects, the leading in wire was blown out and the liquid was sometimes thrown to the height of fifty feet when the metal cylinder did not burst.

At the present time it seems evident that, in these experiments, the lead wire was being suddenly drained of its negative corpuscles. What may properly be called a rarefaction wave was sent along the wire. When in this condition each atom of lead repels every other atom. The lead becomes explosive. There are heat effects involved also, which assist in the separation of the atoms, but which alone do not seem to be capable of accounting for the results.

It seemed to the present writer that it might be of interest to

[1] *Phil. Mag.*, Vol. 46, p. 161.

determine whether the explosive effects would be the same when the negative discharge was sent through the wire as when the positive terminal was used. In the former case a compression wave is sent through the corpuscular nebula within the wire. The repulsion effects are impressed upon the oil surrounding the wire. In the latter case the nature of the action seems to be essentially different, as has been pointed out above.

The wire was placed within a glass tube as shown in the adjoining figure. The internal diameter of various samples varied between one and two millimeters. The length of the tube was 10 cm. The ends of the tube were provided with copper leading-in wires fitting more or less closely the bore of the tube and to which the fine wire was attached, as shown in the adjoining figure. The walls of the tube were from one to two millimeters in thickness. The space within the tube around the wire was completely filled with coal-oil, all air being excluded. The ends of the tube and the leading-in

FIG. 1.

wires were sealed with sealing wax, which held the leading wires in place and secured these wires and the glass tube to supporting blocks of hard rubber.

The source of electricity was an influence machine, provided with a condenser consisting of twenty sheets of glass 66 cm. square, each plate having a tin-foil coating 30 cm. square. These plate condensers were connected in multiple, the tin-foil area being about 20 square feet on each side. A pivotally mounted ground contact could be connected to either terminal of the machine. By means of a similar contact rod either terminal could be connected with one of a set of discharge rods, provided with an adjustable spark gap between the knobs. The other discharge rod was connected with the water-pipe system of the building by means of two No. 8 copper wires in multiple. The apparatus shown in the figure was in this ground line. The ground for the machine was in the yard outside

of the building. The results were the same when the two grounds were thus independent as when they were united.

The wire to be exploded, contained within the glass tube of the figure, was a quarter ampere fuse wire, having a diameter of 0.115 mm. A small copper wire having a diameter of 0.105 mm. was also used with similar results.

A single discharge from either the positive or the negative side of the condenser caused the tube of glass to be shattered into fragments so minute that their impact upon the face of the observer when standing six or eight feet distant, produced no harmful effect. On several occasions, when the discharge came before it was expected, their impact upon the eyes was also harmless.

The small glass tube shown in the figure was enclosed in a larger tube having an internal diameter of about half an inch. This tube was also enclosed in a strip of cardboard. In this way the dust into which the inner tube was converted could be collected. It could only be recognized as glass on examination with a pocket lens.

The effect of the explosion upon the outer tube, the ends of which were open, was found to be in all cases more marked when the compression or negative discharge was sent through the wire than when the discharge rods and wire were connected with the positive terminal. In some cases the rarefaction wave would produce no apparent effect upon the outer tube, while the negative or compression wave would crack it or shatter it into three or four fragments.

In order to make comparative tests, the apparatus shown in the figure was constructed in pairs, the two tubes being cut from adjoining parts of the same glass tube. This was also done with the larger tubes which were placed between the supporting blocks and surrounded the small tube shown in the figure. In some cases two fuse wires or one fuse wire and one copper wire were placed in parallel within the tube. In this way the explosive effects were somewhat varied. In all cases the greater effects of the compression discharge were so marked that there appears to be no doubt of the result.

In order to compare the heat effects of an ordinary direct current, the wire was, by a switch connection, subjected to the current

from a separately excited 250-volt dynamo. The expansion effects then resulted in forcing the oil out through the sealing wax at the ends of the glass tube. No explosive effects were produced. The same experiment was repeated by switching the lead wire into a ground line attached to a city power plant, the impressed potential being 600 volts. The results were exactly the same as in the previous case, so far as explosive effects were concerned. The wire was fused and partly converted into a fine powder.